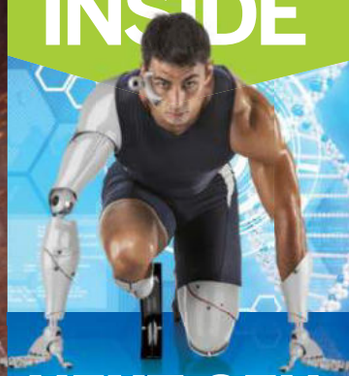
291 AMAZING IMAGES & CUTAWAYS INSIDE

REVEALED: THE DRONES OF WWII

# HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE



NEXT-GEN HUMAN BODY

## REAL-LIFE ZOMBIES

Parasites that possess their animal hosts

## BIRTH OF CIVILISATION

Why we owe everything to a small region in modern day Iraq

+ LEARN ABOUT

- SPACE LETTUCE
- MOTORSPORTS
- PANAMA CANAL
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- SATELLITES

# HOW THE WORLD COULD END

FROM SUPERVOLCANOES TO NUCLEAR WINTERS, THE SCIENTIFIC THEORIES IN DANGER OF BECOMING REALITY

## SCIENCE OF FIREWORKS

Learn how they explode into spectacular shapes

## FUTURE OF POLICING

High-speed drones, gunshot detection systems and more!

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ISSUE 78

# WELCOME

## The magazine that feeds minds!

**Page 20**
Learn about the Large Hadron Collider 2.0

If you're reading this magazine, then we must have survived the giant asteroid attack. Hardly surprising, given it was one of those radical, unfounded claims that seem to circulate every couple of years. This doomsday prediction went viral; it even prompted NASA to assure everyone that the chance of a major collision was pretty slim, and they would know.

Currently, NASA is tracking 1,400 potentially hazardous asteroids, since these space rocks do pose a real threat to Earth. They obliterated the dinosaurs, after all. It's not just rogue asteroids we need to watch out for, though, as we discover on page 26. Don't worry, there are no imminent dangers, and the long-term prospect of the Sun engulfing the Earth is so far in the future (billions of years away, in fact), that we have nothing to fear. That doesn't mean we can't have fun counting all the perilous ways our planet could meet its doom, though, right? Hollywood does it all the time, but our feature is grounded in real science, and there's no Tom Cruise or Will Smith in sight – sorry about that. Grab the popcorn and enjoy!

*Jodie*

**Jodie Tyley**
Editor

## Meet the team...

**Andy**
**Art Editor**
Zombies and organisms invading the body are the stuff of nightmares and horror films, so finding out they are real is pretty scary stuff. Luckily they don't affect us, yet!

**Jackie**
**Research Editor**
In just three years, Curiosity's made some amazing discoveries about the Red Planet. Maybe we don't need to send poor old Matt Damon to Mars after all.

**Katy**
**Production Editor**
I must admit, I'm partial to taking a big sniff of a brand new book – now I know exactly what is tickling my senses when I do that! Take a look on page 18.

**Jo**
**Features Editor**
Watching ISS astronauts eat the first space salad was pretty exciting but I hope there will be some more options on the menu by the time we get to Mars!

**Phil**
**Staff Writer**
With crime fighting robots and a drone fleet at their disposal, the police of the future are certainly not to be trifled with! Take a look on page 38 to find out more.

## What's in store

**Check out just a small selection of the questions answered in this issue of How It Works...**


What happens when we get angry? **Page 19**


How do parasites possess animals? **Page 36**


How are cars adapted to compete in races? **Page 50**


How does the GoPro capture cool action shots? **Page 48**


What has the Curiosity rover found on Mars? **Page 62**


How were drones used in World War II? **Page 79**

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## Meet the experts...

**Laura Mears**
Laura looks to the future this issue as she explores the science and tech that will make us fitter, stronger and live longer. It's amazing to think that there could be pills for anti-ageing and to make you smarter.

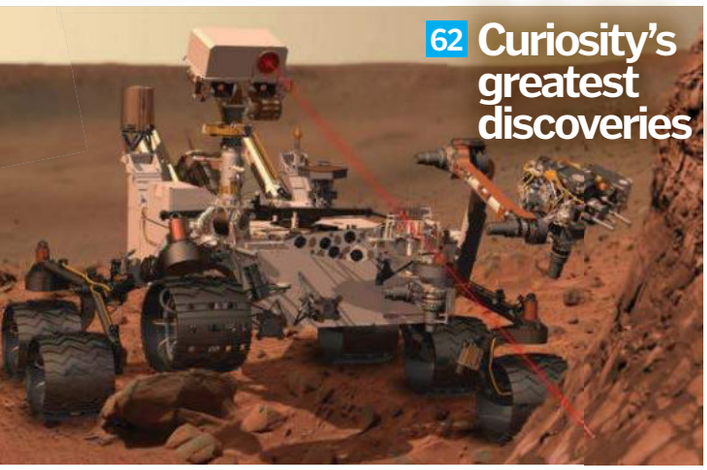
**Gemma Lavender**
This month, **All About Space** magazine's Gemma counts down Curiosity's greatest discoveries so far. See updates as they happen on Twitter, @MarsCuriosity!

**Ella Carter**
Our resident animal expert is getting in the mood for Halloween with a rather disturbing article about real-life zombies! They take control of their animal hosts and get them to do their bidding...

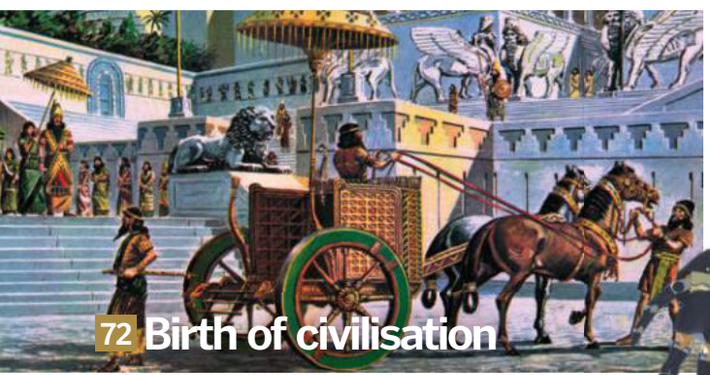
**Lee Sibley**
The Editor of **Total 911** takes us through the process of adapting a road car into a racecar. You can forget about heated seats and air conditioning.

**Ceri Perkins**
As a fan of apocalyptic movies, Ceri enjoyed researching all the ways the world could end in our cover feature, from robot uprisings to supervolcanoes.



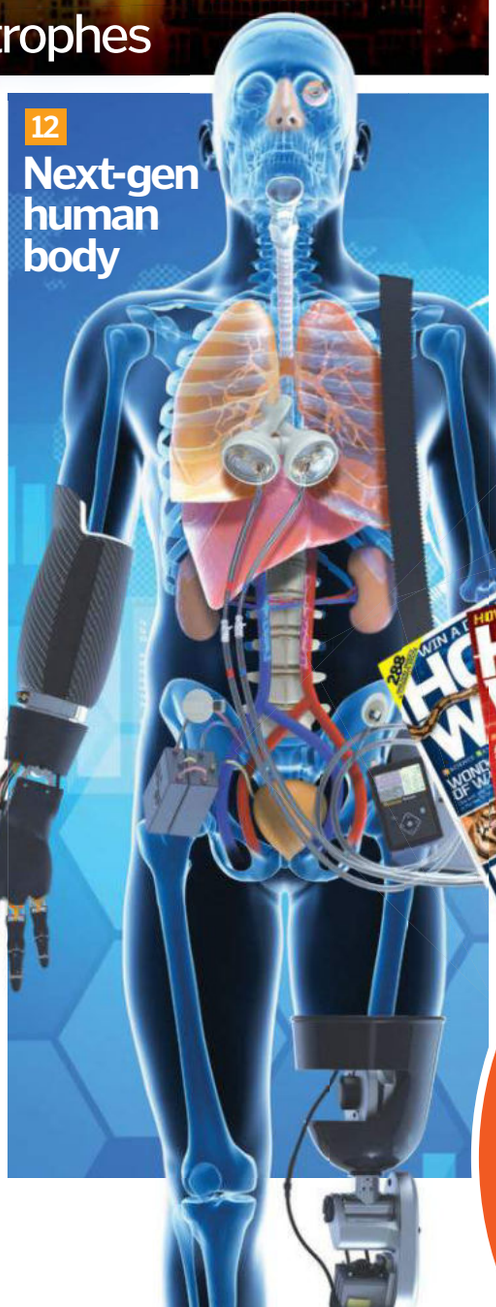






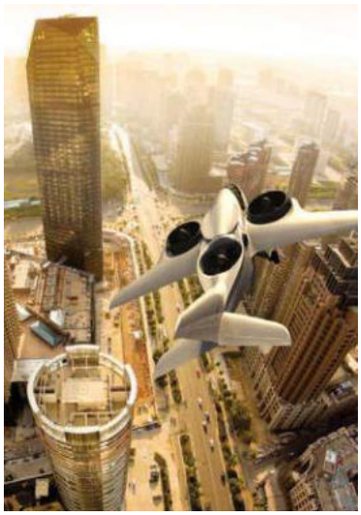








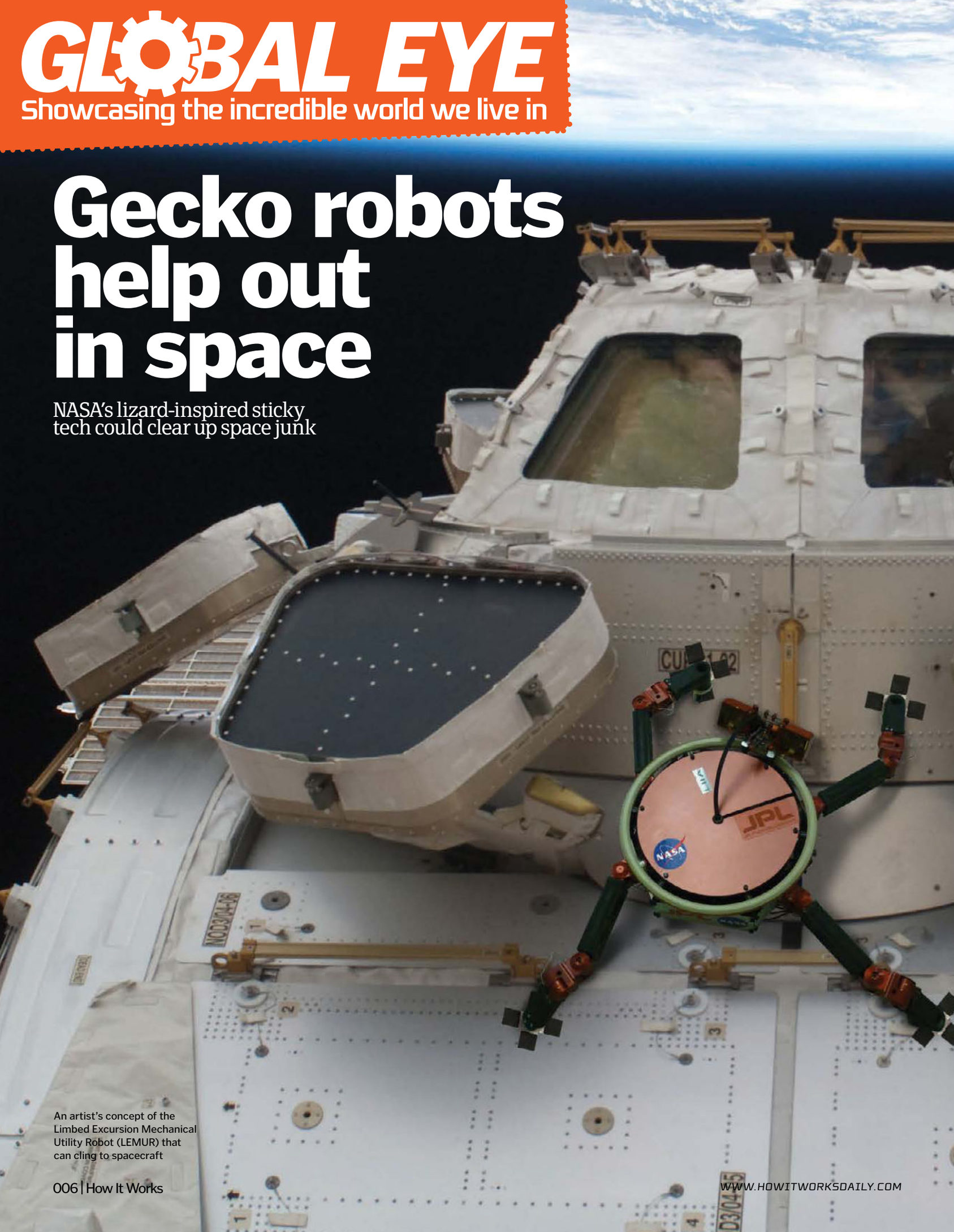
# REGULARS





# Gecko robots help out in space

NASA's lizard-inspired sticky tech could clear up space junk




An artist's concept of the Limbed Excursion Mechanical Utility Robot (LEMUR) that can cling to spacecraft

In space, Velcro is currently the sticking method of choice, with astronauts using it to secure equipment to the interior walls of the International Space Station in microgravity. However, Velcro has the drawback of needing a suitable surface to stick to, so NASA has turned to nature to help find a better alternative.

Its engineers have developed a material inspired by gecko feet that can cling to almost any surface, doesn't leave any residue and won't lose its stickiness over time. The gecko-grippers even work in extreme temperature, pressure and radiation conditions, so the vacuum of space won't be an issue. The adhesive uses tiny synthetic hairs, thinner than a human's, that create van der Waals forces when weight is applied – the same technique used by geckos.

The adhesive has already been tested on a microgravity flight, proving that it can hold the weight of a 100-kilogram (220-pound) human. It is now being used to develop a climbing robot with sticky feet that could be used to inspect and repair the exterior of the ISS. NASA even hopes that this technology could one day be used to grab space junk and clear it from orbit.

## A gecko's sticky feet

Geckos are one of nature's greatest climbers, as they can stick to almost any surface and even cling to ceilings. The secret of their stickiness comes down to the millions of tiny hairs on their feet and some clever physics. Each of the microscopic hairs contain molecules with positively and negatively charged parts, and when these molecules come into contact with another surface, they are attracted to the opposite charges in that surface, forming van der Waals forces. This is then strengthened when the gecko bears its weight down to bend the hairs, so it can unstick itself by straightening them again.

# Door-to-door air travel

## Vertical take-off aircraft lets you skip the trip to the airport

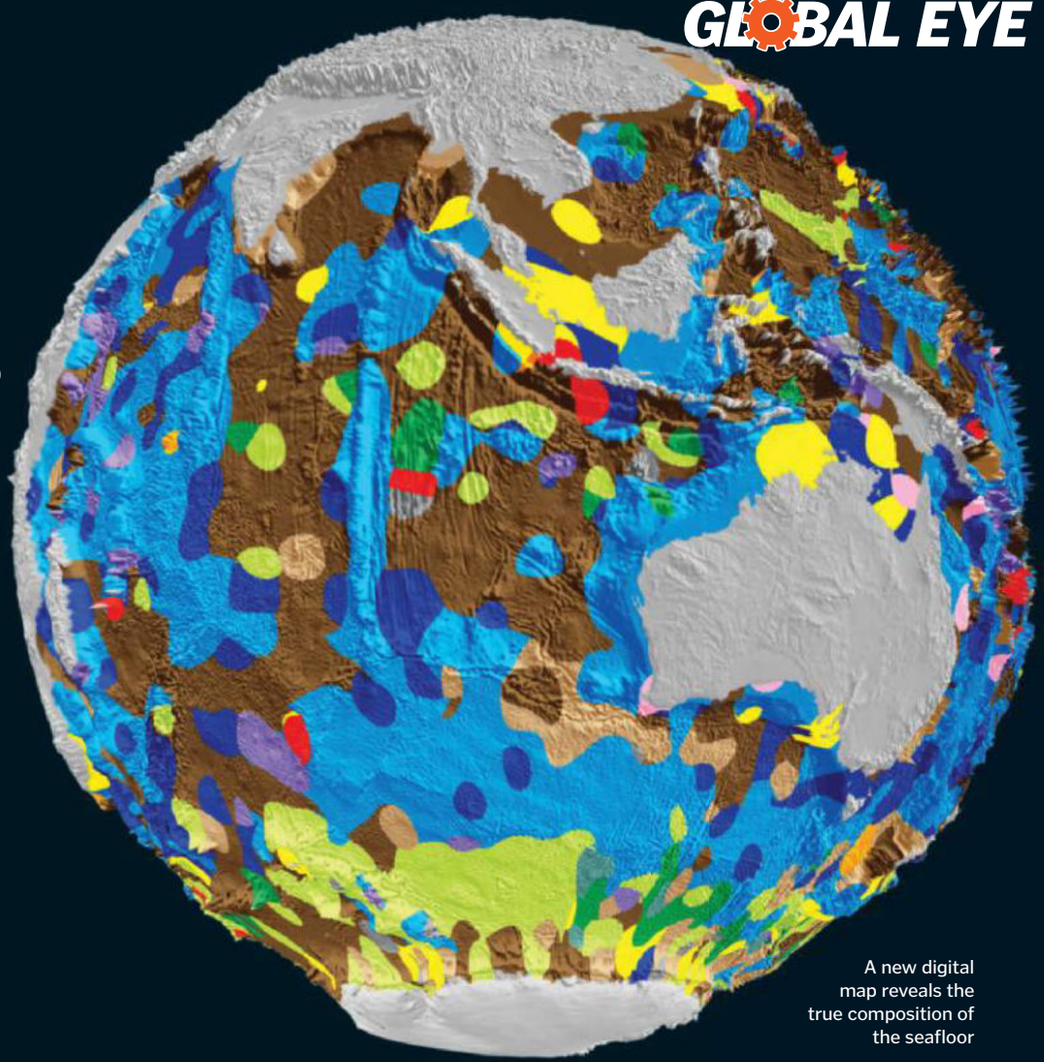
A revolutionary new aircraft does away with the need for runways, and can get you to your destination much quicker than a helicopter. The TriFan 600 from XRI Aircraft is a comfortable six-seat airplane that uses three ducted fans to lift off the ground vertically from any helipad-sized, paved surface. Then, once in the air, the two front fans rotate forwards allowing it to reach cruising speeds of up to 644 kilometres (400 miles) per hour before the process is reversed for a vertical landing. The company has launched a crowdfunding campaign to make their concept a reality and hope it will become the new standard for private business jets.

The TriFan 600 can fly as fast as a business jet and eliminates travel time to and from the airport

# Plankton graveyards discovered

## A digital map of the seafloor reveals long-dead secrets of the deep

The last map to be created of the composition of the ocean floor was drawn by hand over 40 years ago, but now scientists have analysed around 15,000 seafloor samples to produce a more accurate, digital version. The new map shows that the ocean floor is made up of the remains of phytoplankton. When they die, these microscopic creatures lock away carbon within their remains, helping to fight global warming. By studying these remains, scientists hope they can better understand how our oceans have responded, and will respond, to climate change.



A new digital map reveals the true composition of the seafloor

# Sleeping Beauty fish can nap for years

## Scientists hope its technique could be replicated in humans

The incredible African lungfish can sleep for three to five years while out of water, with nothing to eat or drink and without producing waste. The lungfish does this by slowing down its biological clock so that it can survive without sustenance in a low energy state. By studying the processes at a cellular level, scientists hope they can replicate this state of suspended animation in humans. This could give surgeons more time to operate on patients and help to make ultra-long-distance space travel much easier.

When taken out of water, the African lungfish simply sleeps until fresh water becomes available again

GLOBAL EYE

# 10 COOL THINGS WE LEARNED THIS MONTH

## DNA can store digital data

Engineers believe DNA could provide better long-term data storage than hard drives. They tested their theory by encoding DNA with 83 kilobytes of digital text, then warming it to 71 degrees Celsius (160 degrees Fahrenheit) for a week – the equivalent of keeping it at ten degrees Celsius (50 degrees Fahrenheit) for 2,000 years. When they decoded it, the information was perfectly intact.

## Some spiders can skydive

Tropical spiders known as 'flatties' have been seen flinging themselves from treetops and gliding through the air. Unlike most spiders that drop from great heights using strings of silk, these daredevil arachnids prefer to dive headfirst and can even adjust the angle of their front legs to steer their descent. They use this technique to navigate the rainforests of Peru and Panama, while avoiding predators on the forest floor below.

## Having a wide face could get you a job

New research suggests that men with wider faces appear more dominant and powerful, helping them to land high-level jobs. It is believed that a square jaw is caused by higher levels of testosterone, something which also increases the pursuit of dominance. A link has even been found between the face shape of CEOs and the profits of their company.

## Roads could charge your car

The UK Government is going to test electric highways that can wirelessly charge electric cars as they drive. Electric cables buried under the road will generate electromagnetic fields, which can then be picked up by a coil inside the vehicle and converted into electricity.

## Bears are getting stressed out by drones

A new study has revealed that bears show signs of stress when drones are flown near them. Researchers attached health-tracking collars to six black bears, and then conducted several drone flights near to them. The results showed that the heart rate of all the bears increased when the drones were flown within 20 metres (66 feet), putting them at risk of fleeing into a dangerous situation.

## The Moon's atmosphere contains neon

NASA's Lunar Atmosphere and Dust Environment Explorer spacecraft has confirmed that the Moon's thin atmosphere contains neon. There's not enough to make the Moon visably glow, but the supply is relatively abundant and peaks at around 4am, Moon time. Most of the neon is thought to come from solar wind blowing through space.

## Owls are helping to silence wind turbines

In order to fly silently and sneak up on their prey, owls can actively suppress the vibration of their wings to reduce the flapping noise. They do this by converting the mechanical energy of the vibrations into heat, which enables them to remain quiet and also helps to keep them stable in the air. Engineers now hope that they can apply the owl's noise-reduction mechanism to wind turbines and other noisy machines.

## Electric jet boards don't need waves

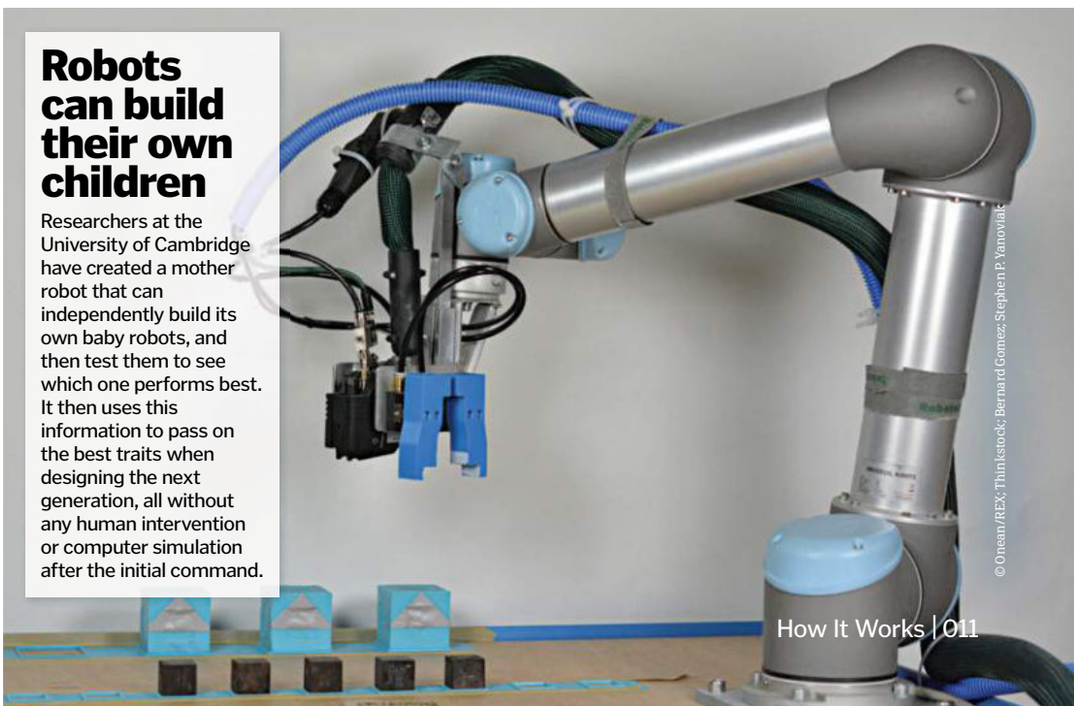
Spanish company Onean has developed a series of jet boards that enable you to surf on even the calmest of waters. The 100 per cent electric boards are powered by brushless electric motors that drive an axial water pump, and feature easily interchangeable batteries that take 120 minutes to charge. The speed can then be controlled by a handheld wireless remote.

## The world's oldest flower was pondweed

A freshwater plant called Montsechia vidalii has been identified as one of the earliest known flowering plants on Earth. It grew in Spanish lakes more than 125 million years ago, when dinosaurs roamed the planet, and bore fruit containing a single seed.

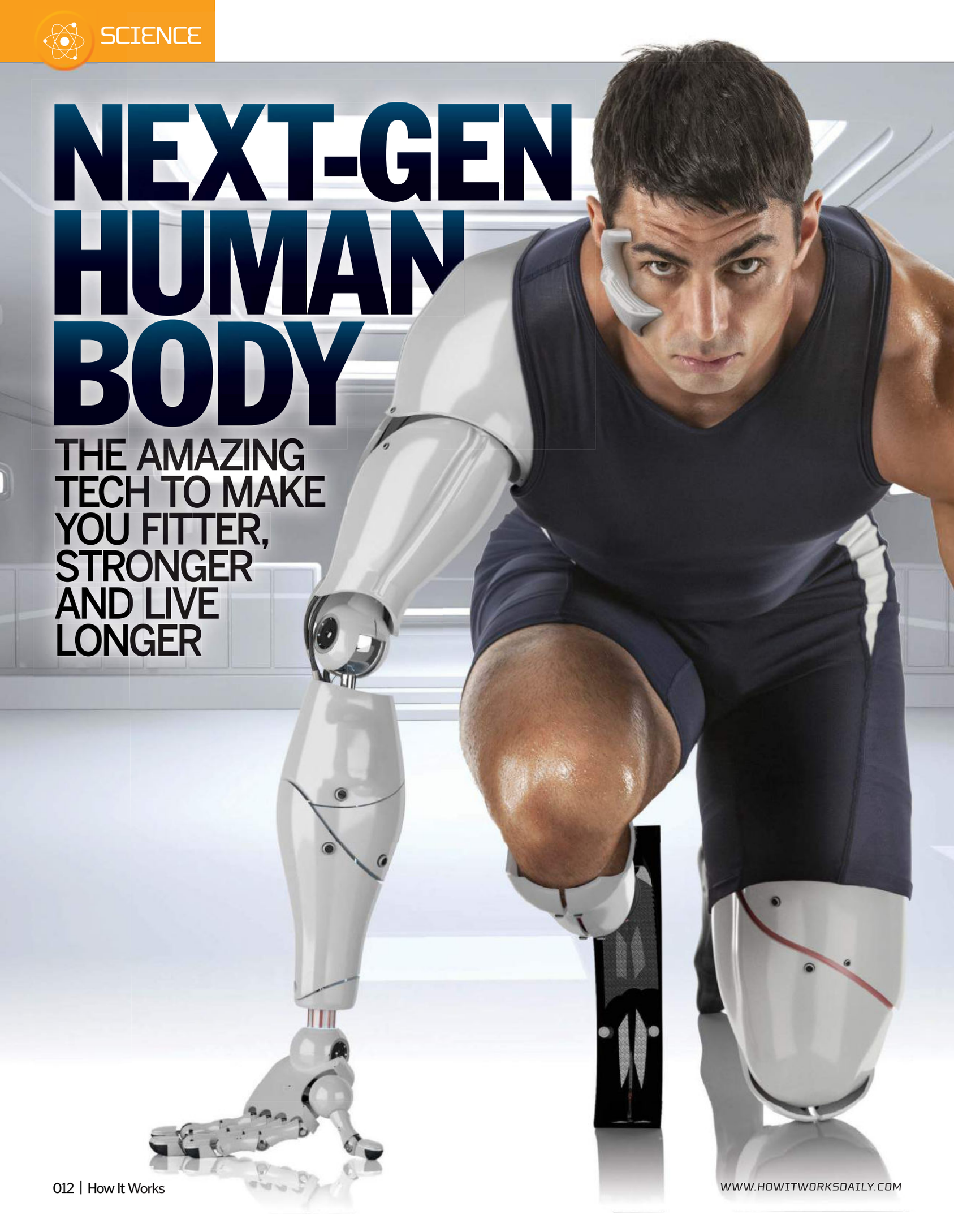
## Robots can build their own children

Researchers at the University of Cambridge have created a mother robot that can independently build its own baby robots, and then test them to see which one performs best. It then uses this information to pass on the best traits when designing the next generation, all without any human intervention or computer simulation after the initial command.



# NEXT-GEN HUMAN BODY

## THE AMAZING TECH TO MAKE YOU FITTER, STRONGER AND LIVE LONGER



Not content with waiting for nature to select humans with the most resistance to deadly pathogens, we developed sanitation, learned about how the immune system works, and invented dozens of vaccinations. We created low-friction implants made from metal alloys and plastics to replace our worn-out joints, implantable pacemakers that can keep our hearts beating, and an arsenal of advanced surgical techniques to repair our bodies when they go wrong. We have completely changed our environments with technology and infrastructure, and in the process we have altered the course of our evolution, defying the rules of natural selection. But have all of our technical advances stopped humans evolving completely?

This is a topic of debate among scientists. In 2013, Sir David Attenborough told the *Radio Times* that he thought humans weren't going to change: "We are the only species to have put a halt to natural selection, of its own free will, as it were." He argued that, because we are now able to ensure that up to 99 per cent of babies survive, the normal processes of natural selection are no longer at play. Some scientists suggest that in our new, human-friendly environment, we are adapting culturally, rather than genetically.

However, in many parts of the world, infant survival is much lower, and many argue that natural selection pressures are still at play. For example, malaria killed an estimated 584,000 people in 2013, according to the World Health Organisation. 90 per cent were in Africa, and most were under the age of five. In areas where malaria is endemic, there is a higher incidence of a genetic disease called sickle cell anaemia, and it is thought that malaria is the driving force behind it. Sickle cell anaemia is caused by a fault in the gene for haemoglobin – the red pigment that carries oxygen in the blood. People with two faulty copies of the gene become very ill, but people with just one copy have some protection against malaria, helping them to survive through to adulthood and pass on their genes.

But what happens in the future? Will there ever come a day when technology becomes so advanced that we are able to defend, enhance and repair our bodies? We delve into the science of the next-gen human body.

## How have humans changed?

Humans have a long evolutionary history but even over the last 100,000 years, there have been some significant changes. 60,000 years ago, an average male human would have measured around 1.83 metres (six feet) tall, but 10,000 years ago his height would have been just 1.63 metres (5.3 feet). Changes in climate and the introduction of farming put evolutionary pressure on the human population, and only those best adapted to the new lifestyle survived.

Our environment continued to play an important role in shaping our evolutionary history as people spread out across the world, with different skin colours, face shapes, and hair types proving to have advantages in different environments. Even moving into cities has shaped human evolution; living in close proximity increases the potential for transmission of disease, killing some members of the population before they have a chance to pass on their genes.

Now, with improved diet and health care, humans are starting to get taller again, and vaccinations are able to control at least some infectious diseases. Perhaps surprisingly, our brains are smaller than they once were. We have lost about a tenth of our brain size, and most of the decrease has occurred in the last 6,000 years.

These human skull fragments found in Ethiopia are over 100,000 years old

# HOW SCIENCE CAN MAKE US SUPERHUMAN

## Advances in biology are enabling scientists to modify the human body

Before the age of modern medicine, we were all but powerless to the flaws of the human body, but today we are able to intervene. In some ways, we are already superhuman. Diseases that plagued our recent ancestors are held at bay by vaccinations, and millions of people live with technology implanted into their ears, eyes and hearts. Precision surgery can repair delicate structures inside the body, and genetic techniques are starting to enable us to predict and prevent disease, as well as intelligently design new treatments.

As technology advances, the opportunities to augment our biology are increasing at an unprecedented rate, and the technologies of the future have the potential to take the human body beyond what nature intended. Researchers looking into the science of ageing hope to be able to delay, stall or even reverse the process, and scientists working on repair and regeneration are developing ways to fix damage that would once have been irreversible.

Whether these bold ambitions are actually possible is yet to be seen, but we are gaining more and more control over our own biology, and science continues to have the potential to make us fitter, faster, stronger and smarter than ever before.

## The molecule of youth

The secrets of human ageing are sought by scientists across the globe, and some seem to be getting close to the answers. As we age, our stem cells become dysfunctional, and are less able to repair damaged tissues.

Researchers at the University of California, Berkeley have been trying to find out why, and they think that one of the culprits might be a molecule called TGF-beta1. When they used a small molecule drug to block TGF-beta1 in mice, the stem cells in their muscles and brains behaved more youthfully again.

TGF-beta1 is a protein involved in deciding when cells grow and divide

## Connecting nerve cells

Stanford University scientists have found what they think is an 'on/off' switch for the growth of new connections in the brain. The molecule, called PirB, sits on nerve cells and normally, nothing happens. But when other molecules stick to PirB, this sends a signal that stops new connections from being made. The team made a decoy version of PirB to catch the joining molecules, switching new synapse formation on again.

If the PirB decoy works in humans, it could be used to restore vision or to help the brain to repair after a stroke

## Lab-grown muscles

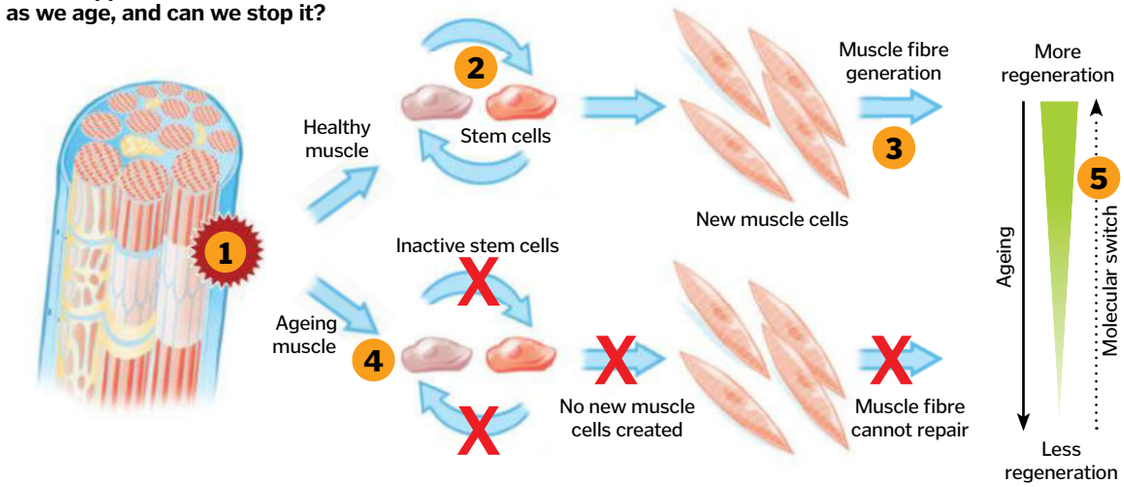
Scientists at Ohio State University and the Center for Gene Therapy at Nationwide Children's Hospital have been looking into the effects of two molecules involved in muscle growth. Myostatin normally limits muscle growth, and follistatin blocks its action, promoting muscle growth.

People and animals with genetic faults in the gene for myostatin have much larger muscles than usual, so the scientists wanted to know whether increasing the amount of myostatin-blocker follistatin would have the same effect. They used gene therapy to deliver follistatin genes to the muscles of monkeys, and their muscles increased in strength and size by around 25 per cent.

Super strength is one thing, but super regeneration might be better. Researchers at Duke University have been developing techniques to grow muscle in the lab, and by paying close attention to recreating the unique environment where stem cells can survive, their tissue is able to repair when damaged. The next step is to find out whether it can get its own blood supply and connect to the nerves of a living recipient.

## Reversing the ageing process

**What happens to our muscles as we age, and can we stop it?**




**1. Damage**
Damage to the muscle releases chemical signals that alert cells in the surrounding area.

**2. Stem cell**
Muscle has its own population of stem cells called satellite cells. These can divide to form new muscle cells.

**3. Repair**
The satellite cells produce new muscle cells, which help to repair the damaged muscle fibre.

**4. Ageing**
Our satellite cells eventually stop working. They no longer divide in response to injury so muscle can't be repaired.

**5. Reversing decline**
Scientists in Spain have identified the molecular switch responsible, and found that blocking it in mice allowed stem cells to start repairs again.

# The future of medicine

In Britain, average life expectancy hovered around 40 years of age for hundreds of years until the 1800s, when something changed. The Industrial Revolution swept across the nation, and science and technology transformed the way we live our lives.

We have already augmented our reality with sanitation, vaccination, antibiotics, medical imaging, and a whole host of other innovations, and as technology improves and our understanding of the human body increases, there is scope for even more dramatic change.

For example, wearable technology is just getting started, but the gadgets that can currently track steps and heart rate could one day help to monitor all of our vital signs. Biometric sensors are being developed to be worn inside clothes, or to be implanted, and could one day provide real-time feedback and advice on our health.

Technology in the lab is also rapidly changing the way that we design and develop medicines. Using the latest techniques in genetics to identify the underlying causes of disease, scientists are developing precision drugs. In the future, it is hoped that patients will receive treatment based on their own individual genes.

# Life-saving science

## Cures

Vaccinations protect millions from infections like measles and the cancer-causing HPV, and have eradicated smallpox worldwide. Scientists are now developing vaccines to eradicate polio, HIV, malaria and many more.

## Education

Advances in medical research and communications technology mean that we have access to more information than ever before. The more we know about how the body works, the better equipped we are to look after it.



## Advanced surgical techniques

Sophisticated robotic surgery systems are being developed to enable surgeons to perform intricate procedures without needing to be in the same room as their patient, and advances in imaging technology allow for minute precision.



*"The more we know about how the body works, the better equipped we are to look after it"*

## Better diets

Huge population studies – like the international EPIC study, which is tracking an incredible 521,000 people – are analysing the effects of diet on our risk of different diseases, helping people to make informed choices about their food.

## Better medicines

The more we learn about the human body, the better we are becoming at targeting medicines at specific problems. With advances in genetics, scientists and doctors are working to design drugs that are personalised to each patient.



# Changing our genes

Gene therapy, the ability to correct faulty genes, has the potential to be life-changing. However, several scientific and ethical hurdles still need to be overcome.

In the 1990s, scientists developed a virus that – instead of causing illness – could deliver healthy copies of a gene into the bodies of children with Severe Combined Immunodeficiency. Early trials showed that the treatment could successfully combat the disease, but some of the children treated went on to develop leukaemia.

This is because when a virus delivers a gene into a human cell, it slots it into the existing DNA. However, the position it chooses is not always predictable. If the gene is inserted in the middle of a region of DNA that is important, it can lead to serious health problems.

We still have more to learn about the science and technology of manipulating our own genetics, but in the future changing our genes will become much easier. However, the consequences of this kind of scientific advance are unknown, and there is great academic, ethical and political debate about whether manipulating our genetics, or those of our unborn children, is wise.

Huge international projects are underway to untangle the links between genetics and disease

# AUGMENTED HUMANS

## What does the future look like for bionics and prosthetics?

In the early days of bionic body parts, scientists struggled to match even the basic functions of the human body, but as technology evolves, it is becoming clear that one day bionics could outstrip our natural capabilities. Will there ever come a day when people are willing to part with perfectly healthy limbs or organs to upgrade to a man-made alternative?

High-tech prosthetic limbs can now be trained to respond to the wearer's own nervous system, and new advances in sensor technology are starting to provide sensory feedback. However, there is still a long way to go before they are able to match the full range and dexterity of human movement and the quality of natural tactile feedback.

But while matching human biology perfectly remains a significant challenge, technology could provide us with the power to make changes that nature never intended. Using modern materials, we could make limbs far stronger than human arms and legs, with a greater range of motion, or with the ability to resist extreme environments.

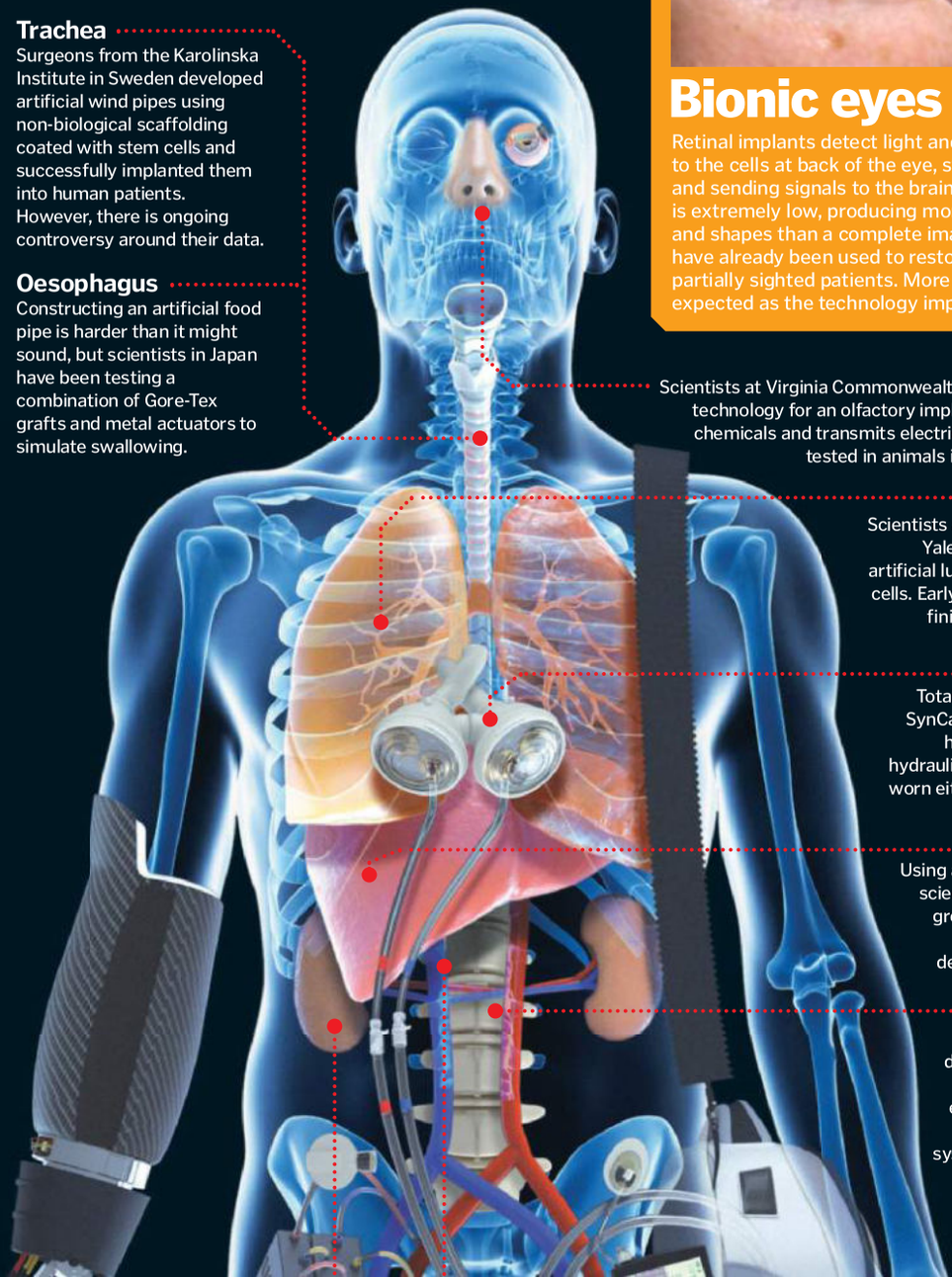
Biology can also be augmented with technology to improve on our natural abilities. In Italy, the Perceptual Robotics Laboratory is developing a wearable robotic exoskeleton called the 'Body Extender'. Using the machine, a strapped-in operator can lift an incredible 50 kilograms (110 pounds) with each arm, and can grip with ten times a human's natural force. And, at the University of Washington, scientists are developing contact lenses containing LEDs that can be activated using radio waves. In the future, this kind of technology could be used to produce a virtual display, conjuring words and images across the front of the eye.

However, the idea of replacing or enhancing healthy human body parts with technological alternatives opens many debates. Most performance-enhancing drugs are already banned in competitive sports because of their potential health risks, and advancements in bionic technologies may pose similar problems. There is also real concern surrounding the ethical issues of augmenting our own biology, particularly in the military, where there might be the potential to create 'super soldiers'.

Looking far into the future, advancements in bionics could ask even more challenging questions. For instance, is there a limit on the number of body parts that can you replace with artificial parts before you are no longer human? And what is it that makes us human in the first place?

## Human 2.0

**With advances in technology, researchers are preparing humanity for an upgrade**

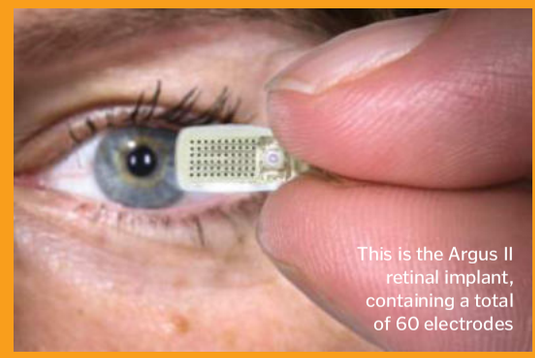


### Trachea

Surgeons from the Karolinska Institute in Sweden developed artificial wind pipes using non-biological scaffolding coated with stem cells and successfully implanted them into human patients. However, there is ongoing controversy around their data.

### Oesophagus

Constructing an artificial food pipe is harder than it might sound, but scientists in Japan have been testing a combination of Gore-Tex grafts and metal actuators to simulate swallowing.



This is the Argus II retinal implant, containing a total of 60 electrodes

## Bionic eyes

Retinal implants detect light and send electrical impulses to the cells at back of the eye, stimulating the nerve cells and sending signals to the brain. Currently, the resolution is extremely low, producing more of a sense of light, dark and shapes than a complete image, but the implants have already been used to restore sight to blind and partially sighted patients. More sophisticated images are expected as the technology improves.

### Nose

Scientists at Virginia Commonwealth University have patented the technology for an olfactory implant system that detects odour chemicals and transmits electrical signals. It is currently being tested in animals in preparation for human trials.

### Lung

Scientists at Harvard Medical School and Yale University have been growing artificial lung tissue in the lab using stem cells. Early results are promising, but the finished product is a long way off.

### Heart

Total artificial hearts, developed by SynCardia and AbioMed, replace the human heart with pneumatic or hydraulic pumps powered by batteries worn either outside or inside the body.

### Liver

Using a combination of 12 chemicals, scientists at MIT have been able to grow functioning liver cells in the lab, paving the way for the development of an artificial liver.

### Spinal cord

Researchers in France have developed a spinal cord implant that is able to deliver both electrical and chemical signals, mimicking the human nervous system. In tests, 'e-Dura' allowed paralysed rats to walk again.

This advanced prosthetic arm was made by DARPA (the Defense Advanced Research Projects Agency), part of the US Department of Defense

## Bionic arms

The latest prosthetic arms are packed with technology. Each finger has its own individual motors, and their positions are tracked at all times by microprocessors. Pressure sensors adjust grip automatically when objects start to slip, and movement is controlled by the wearer's own nerves, with the prosthetic picking up tiny electrical signals under the skin in the arm or shoulder, or even nerve signals in the brain.

The latest developments are also giving prosthetics the ability to detect and transmit touch. Scientists at the Case Western Reserve University in Ohio have managed to wire pressure sensors into the nervous system of human patients, allowing them to feel pressure and texture.

### Kidneys

Researchers at the University of California, San Francisco are developing an implantable artificial kidney using silicon nanotechnology to filter the blood, and real human kidney cells to reabsorb salt and water.

### Pancreas

Researchers at the University of Cambridge have developed an artificial pancreas. A glucose sensor implanted under the skin sends a wireless message telling an insulin pump to deliver the correct dose.

## Building brains

The human brain is the most complex structure in the known universe. Replicating it is one of the biggest scientific challenges ever attempted, and different teams are trying different approaches.

The Blue Brain Project, a collaboration between IBM and Swiss university EPFL, has simulated part of a rat's brain containing 10,000 neurones. By repeating these sections, the team hope to be able to simulate a whole brain.

However, this won't be easy. In 2014, the K computer in Japan managed to simulate one second of activity from one per cent of the human brain. This feat required over 700,000 processor cores and more than 1.4 million gigabytes of RAM, and it still took 40 minutes to complete.

Simplifying the problem is having promising results though. In 2015, the Human Brain Project created a working simulation of a mouse brain by condensing its 75 million neurons to a simplified model of just 200,000 neurons.

The human brain has over 100 trillion connections, known as synapses

## Bionic legs

One of the major hurdles in prosthetic leg design is adjusting between sitting and standing. The majority of older models use switches, but with the addition of robotic sensors, cutting-edge prosthetic legs are now able to intelligently adapt. Not only can they detect movement and weight distribution, but some are also wired in to nerve signals from the thigh muscles, which contain information about the normal position of the ankle.

These sophisticated legs can closely match the capabilities of biological legs, and with a few upgrades, they are even better. For example, changing the shape of the feet can improve climbing ability beyond normal human limits.

Sophisticated prosthetics can stand up to extreme challenges



Bionic illustration by Nicholas Forder

*DID YOU KNOW? In 2012, the US Federal Government spent $580 million on medical and prosthetics research for war veterans*

# Antioxidants explained

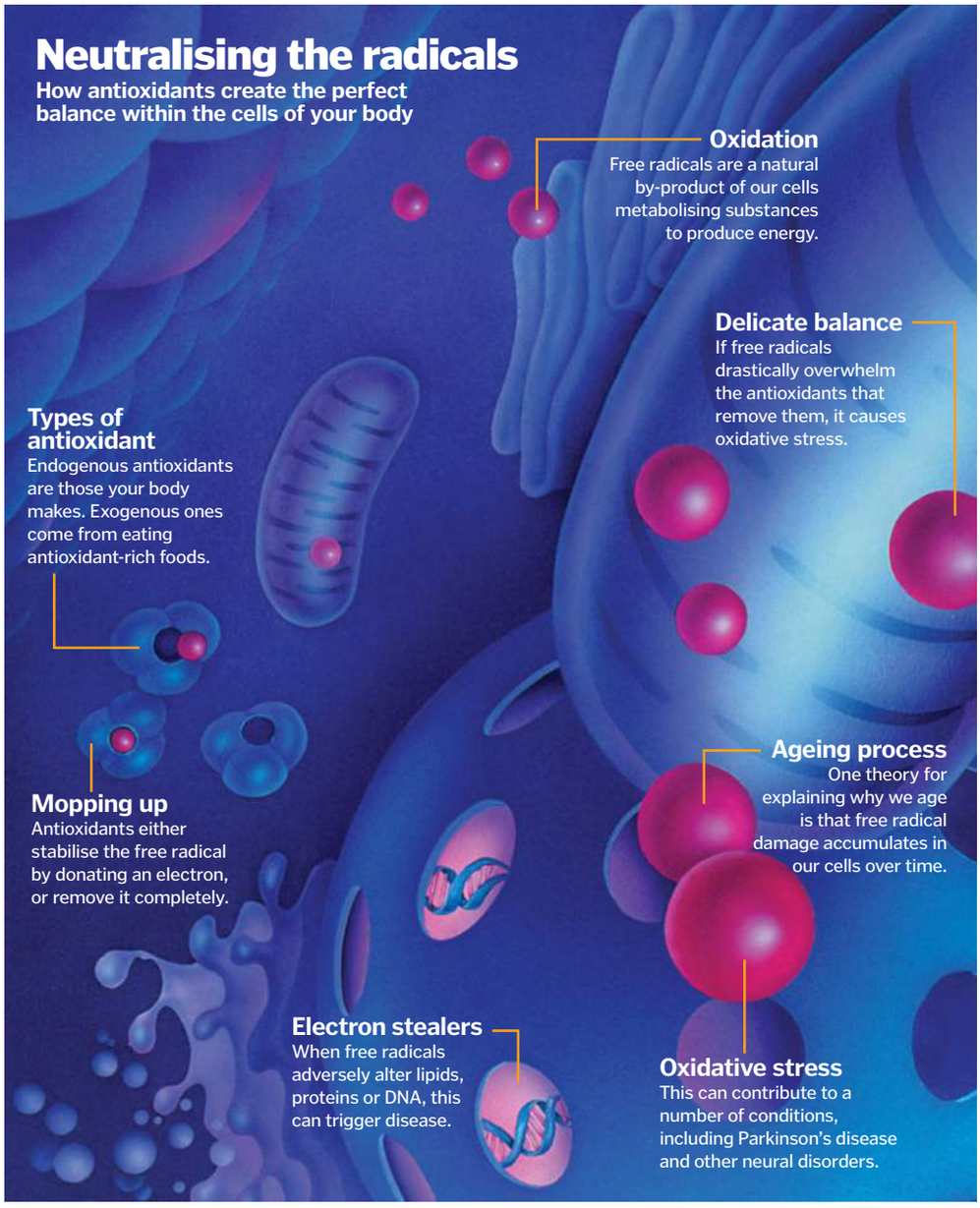
## The molecules that help to protect your body

Antioxidants are good for us because they combat an excess of molecules in our cells known as 'free radicals'. These are unstable molecules produced during natural cell processes, but can also come from external sources such as smoking and processed food. Free radicals play a key role in our biology, but an excess in our system is generally bad news.

Free radicals have an unstable number of electrons, and to make up the numbers they will try to take electrons from other molecules in a cell. This results in more unstable molecules, creating a domino effect. When important molecules such as DNA are altered, this can cause problems.

To combat this, antioxidants come to the rescue – the theory is that these substances can neutralise free radicals by either supplying the electron needed to stabilise the molecule, or by breaking down and removing the radical. Our bodies contain enzymes that act as antioxidants, but we cannot synthesise all of them, so we obtain the rest from our diet.

Antioxidants can be found in a variety of foods, even coffee and dark chocolate




# What is new book smell?

## Love it or hate it, here's how this distinctive odour is made

There's nothing quite like getting the new bestseller and taking in the whiff of its pages. But what is 'new book smell'?

In volumes that are hot off the press, this scent is derived from the chemicals used in their production. The various chemicals react with one another and with the environment, giving off volatile organic compounds, which are what we sniff as we flick through.

It's hard to pinpoint the exact factors that cause new book smell, as thousands of different chemicals are used. When paper is made, it is treated to give specific finishes; for example, hydrogen peroxide is used to bleach the fibres and sodium hydroxide boosts pH. During printing, the inks for the words and pictures also add their own chemical signature. Then when the book is assembled, numerous adhesives, such as vinyl acetate ethylene, are used to securely fasten the pages together. Mix all of these chemicals together, and you have your new book aroma.

Crack the spine and take a sniff: it's a complex cocktail of chemical compounds

# The science of anger

## How does this primal emotion override our normal thought processes?

As far as we know, anger is one of the oldest and most primitive forms of emotion. It is believed to have been hard-wired in our brains many thousands of years ago, to help us survive tougher times. Back then, resources like food, potential mates and shelter were relatively scarce. Anger was therefore a vital emotion, giving our ancestors the necessary drive and power to survive when their safety, or chance to mate, was threatened.

Although our lives are less frequently in danger than our ancestors', our brains still react to certain anger triggers, one of which is being treated unfairly. As soon as someone shouts at you or gives you an angry look, the amygdala in your brain sounds the alarm, prompting the release of two key hormones – adrenaline and testosterone – which prime the body for physical aggression.

As well as the amygdala, the prefrontal cortex is also activated by the anger trigger. This part of the brain is responsible for decision-making and reasoning, making sure you don't react irrationally to the situation. According to studies, the time between initially getting angry and the more measured response from the prefrontal cortex is less than two seconds. This would explain the popularity of the age-old advice of counting to ten if you feel your blood boiling.

It's widely accepted that men and women feel anger differently. Women are more likely to feel anger slowly build up, which takes time to diffuse, whereas men are more likely to describe the feeling as a fire raging within them that quickly eases. This is thought to be due to men having a larger amygdala than women, and is why a man is statistically more likely to be aggressive than a woman.

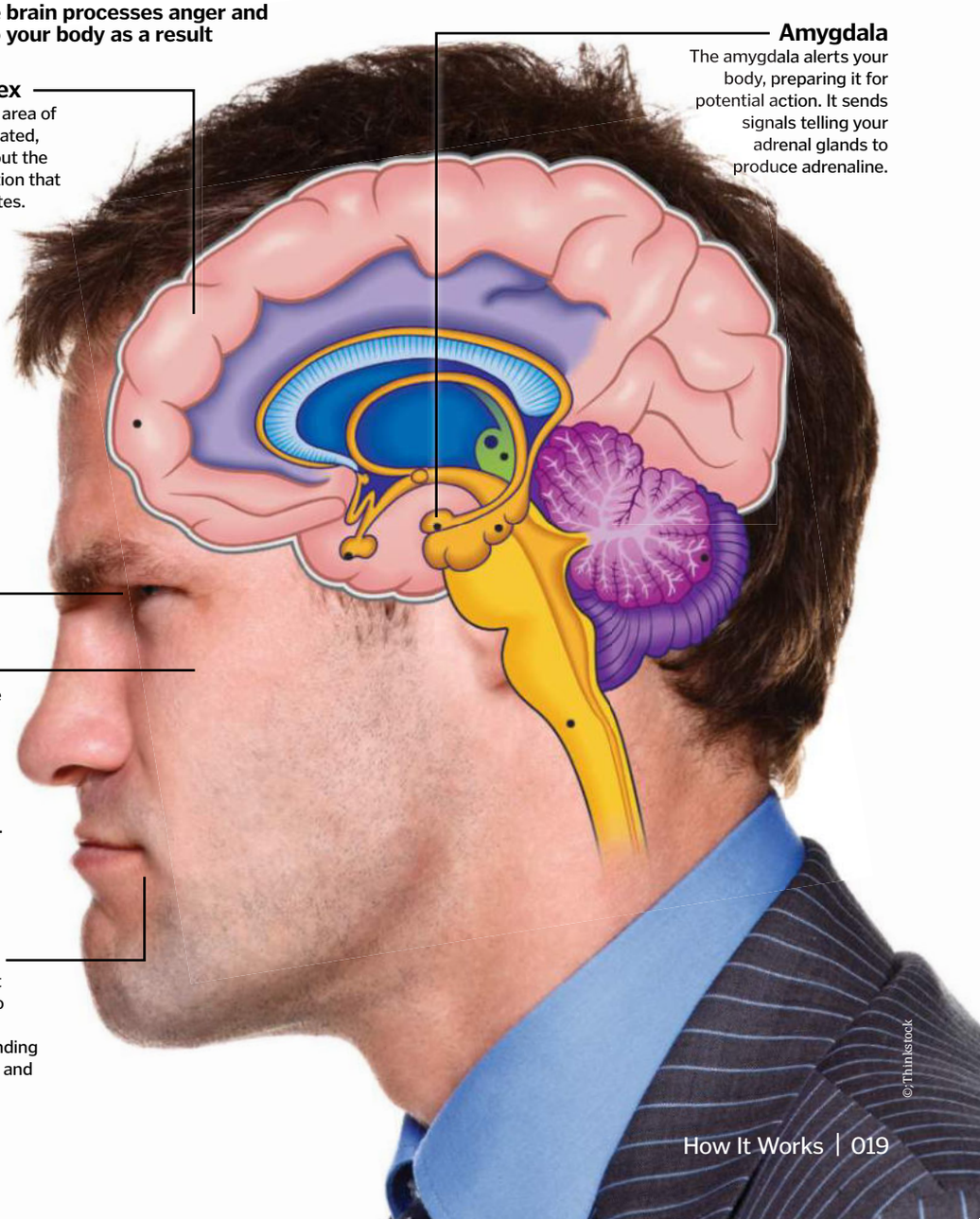
## Can getting angry be good for you?

Many people view anger as a negative emotion that wastes energy and has no benefits. Yet as with all human emotions, anger has evolved to serve an evolutionary purpose. Having said this, getting angry will only have a positive effect if it is used in the correct way. If we sit down and discuss why someone or something has made us angry, then anger is working in the right way; if we can't regulate our anger response, it's unlikely to improve a situation in the long run. Studies have shown that releasing anger in a rational way is actually good for you. On the other hand, storing anger up is known to negatively affect certain people, potentially leading to depression. Constant, chronic anger can lead to high blood pressure and even heart disease in the long term.

Explaining why something has made you angry is much more likely to resolve an issue than exploding with rage

## Inside your brain

**Find out how the brain processes anger and what happens to your body as a result**



**Amygdala**
The amygdala alerts your body, preparing it for potential action. It sends signals telling your adrenal glands to produce adrenaline.

**Prefrontal cortex**
The decision-making area of the brain is also activated, and acts to balance out the potentially rash reaction that the amygdala promotes.

**Trigger**
Seeing or hearing a trigger event can spark an anger response from the amygdala in just a quarter of a second.

**Flushing red**
The rise in adrenaline causes blood vessels to dilate to improve blood flow. The dilation of the veins in your face can make your face flush.

**Teeth grinding**
People have different physical responses to anger, but common reactions include grinding teeth, clenching fists and tensing muscles.

# Large Hadron Collider 2.0

## The upgrades and discoveries of the most powerful particle smasher on the planet

The world's most powerful particle accelerator is back, and it's better than ever. After being shut for two years of planned repairs and maintenance, the Large Hadron Collider (LHC) is smashing particles together at a record-breaking 13 tera-electronvolts, almost double the energy it was using in 2013.

Researchers at CERN hope this vastly improved energy output will allow more intricate studies of the Higgs boson – a particle that could explain why matter has mass – which was famously discovered in 2012. The increased energy should mean that Higgs boson particles are generated more frequently (it should be able to generate ten times as many as during the LHC's first run), helping researchers measure them more accurately and probe their rare decays. Furthermore, researchers hope that a more powerful LHC will be able to safely conduct more extreme experiments, which scientists believe will better simulate the conditions of the early universe.

In July 2015, the LHC's latest discovery was made: the pentaquark. This not only represented a brand new particle, but also gave researchers a way to group together quarks (the constituent particles of protons and neutrons) in a brand new pattern. This in turn could help us understand how these subatomic particles are formed.

Physicists have also set their sights on finding dark matter, which is known to make up around 85 per cent of all matter in the universe but whose nature is unknown. The only reason we know it exists is due to its gravitational effects, holding the universe together. Scientists have theories about the characteristics of the particles required for dark matter, but it may be that they uncover something else entirely. This is what makes the LHC experiments so exciting; no one really knows what it will find between now and 2018, when the next set of upgrades have been scheduled.

**Improved cooling system**
The LHC's specialised magnets must be kept very cold, which has led to the improvement of the cryogenics system responsible for this.

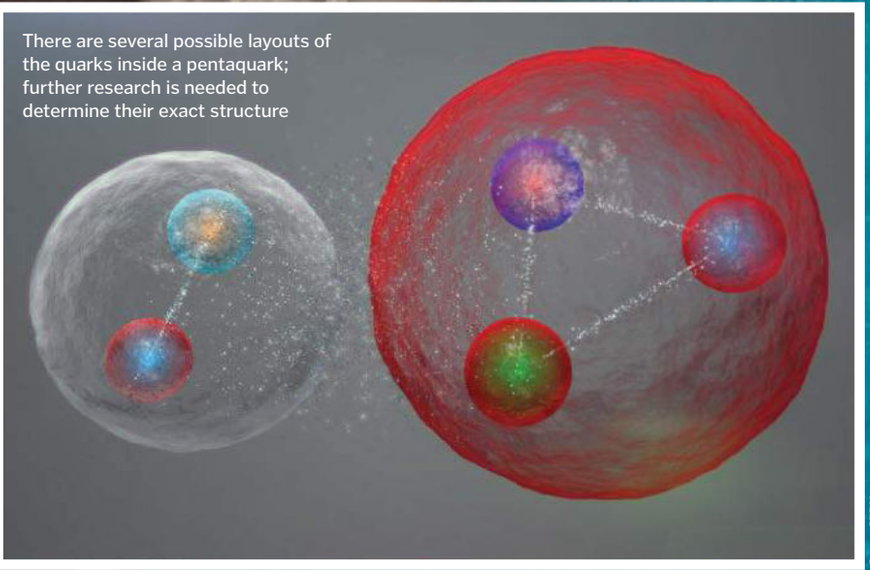
**Secure vacuum**
To prevent electron clouds from interfering with the beam, the beam pipe has been coated with a special non-evaporable substance to take up electrons.

**Tougher connections**
More than 10,000 metal shunts have been fitted to the many electrical interconnections between the LHC's magnets, protecting them if there is a fault.

*"This vastly improved energy output will allow more intricate studies of the Higgs boson"*

**Higher energy beams**
One of the most significant improvements is the energy of collisions, which will now be 13 tera-electronvolts compared to eight tera-electronvolts in 2012.

**Thinner beams**
As beam widths decrease with increasing energy, the LHC's beams will now be more tightly focused to allow more collisions and interactions during experiments.



There are several possible layouts of the quarks inside a pentaquark; further research is needed to determine their exact structure

# What is keratin?

## The secret behind some of nature's toughest materials

Keratin is a protein found in humans and animals alike. There are two main types and each has a slightly different structure. Alpha keratin, which is the main structural component of hair, skin, nails, hooves and the wool of animals has a coiled shape, whereas the tougher beta keratin, found in bird beaks and reptile scales, consists of parallel sheets. Both are composed of amino acids – the building blocks of all proteins that make up a large proportion of our cells, muscles and other tissues.

The flexibility of the keratin depends on the proportion of different amino acids present. One particular amino acid, called cysteine, is responsible for forming disulphide bridges that bond the keratin together and give it its strength. The more cysteine the keratin contains, the stronger the bonds will be, so more can be found in rigid nails and hooves than in soft, flexible hair. Incidentally, it's the sulphur within cysteine that creates the strong odour of burning hair and nails.

Curly hair has more bonds between amino acids in the protein chain that makes up keratin

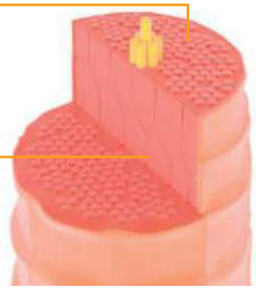
### Alpha keratin

**How this protein makes up your hair**

**Alpha helix**
Keratin is made of coils of amino acids held together by peptide bonds to form polypeptide chains.

**Protofibril**
Three alpha helices twist together to form a protofibril, the first step towards creating a hair fibre.

**Microfibril**
An 11-stranded cable is formed by nine protofibril joining together in a circle around two more protofibril strands.



**Macrofibril**
Hundreds of microfibrils bundle together in an irregular structure to create a macrofibril.

**Hair cell**
These macrofibrils join together within hair cells, making up the main body of the hair fibre called the cortex.

# Inside dust

## From skin cells to space rocks, there's a long list of particles lying around your home

It's a myth that dust in our homes is only made up of dead skin. In fact, it contains an average of 9,000 different species of microbes, alongside a powdery potion of animal hairs, pollen, decomposing insects, fabric fibres and much more. The majority actually comes from outside, having been blown in through windows and doors or carried in on your clothes or shoes. The rest comes directly from the people, animals or objects inside the house.

Thousands of different species of bacteria and fungi are commonly found in dust, as well as tiny creatures called dust mites, which produce allergens. However, among all of these disgusting things, you might also find something to treasure. Dust has been found to contain tiny particles of space dust called micrometeorites, which were once part of comets and asteroids, and you should be able to pick them out using a very strong magnet.

A coloured scanning electron micrograph of household dust containing pet hair, insect remains and pollen

Household dust is mostly harmless and 80 per cent of it can be removed by cleaning regularly

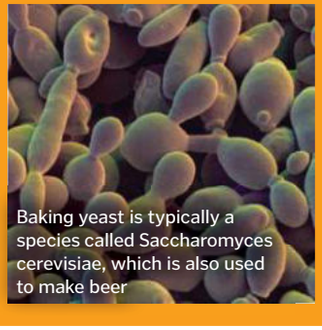
# Baking bread

## How chemistry and biology help to make the perfect loaf

Ancient Egyptian hieroglyphs show that humans have been baking bread for thousands of years. The first attempts consisted of ground wheat and water that was left to harden in the Sun. It's possible that one mixture was left longer than usual and the naturally occurring yeasts enabled the dough to ferment. The resulting loaf would have risen, leading the Egyptians on a mission to isolate the yeast so that it could be added to every batch of bread. This key ingredient is just one part of the amazing chemical and biological processes that create a food that's enjoyed all over the world. Read on to discover how to conduct this tasty experiment at home.

## What is yeast?

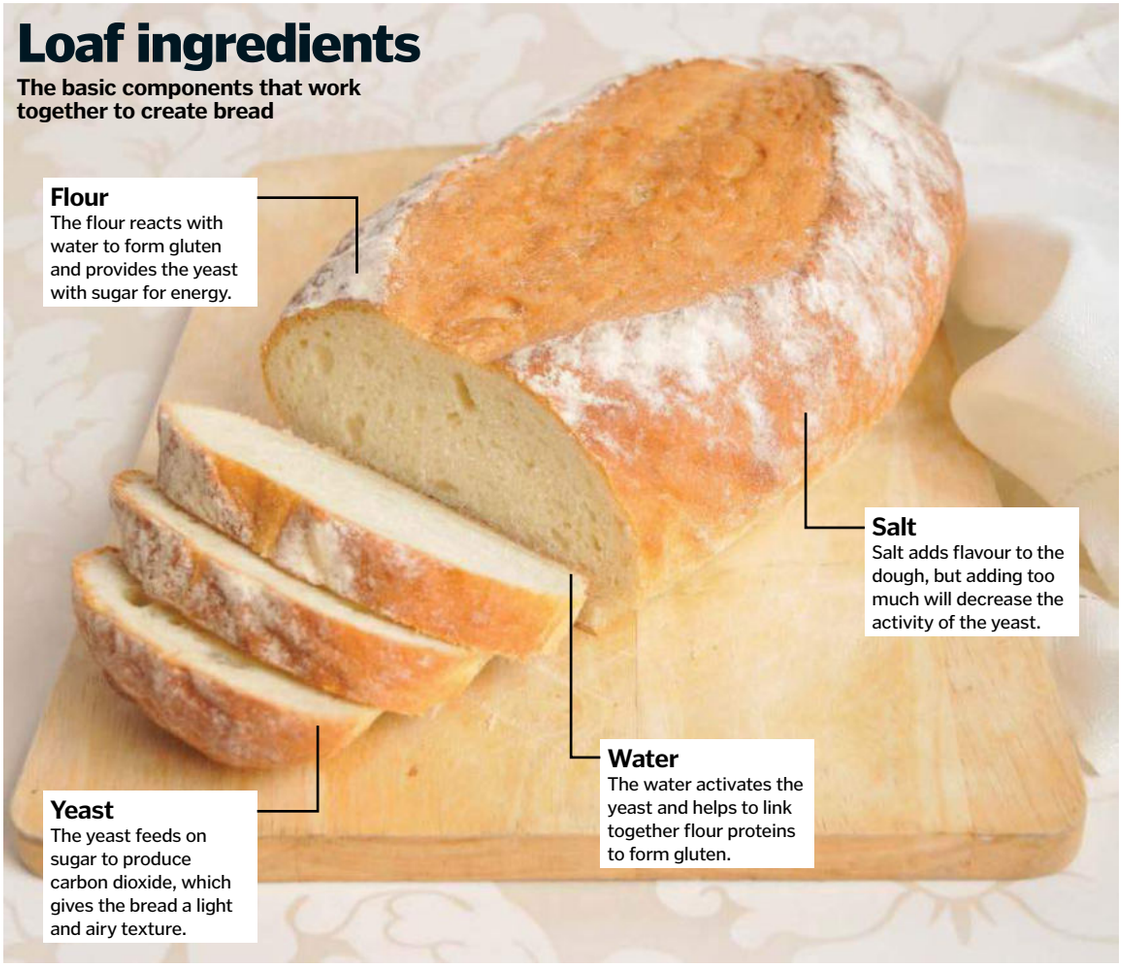
It's strange to think that you are adding a living organism into your bread dough, especially when you consider it is actually a fungus. Thankfully though, the packets of yeast you buy at the supermarket contain a different species from the ones that cause nasty infections. Baker's yeast usually comes in the form of capsules made from dried yeast. When these capsules come into contact with moisture, the shells dissolve to release the live yeast inside. This gets to work feeding on the sugar created by enzymes that digest the starch content of the flour. As well as carbon dioxide, this process also produces alcohol, which burns off during baking but leaves behind a slightly sour flavour. Yeast works best at warm temperatures, so it is best to leave the dough to rise in a warm place, but cover it to prevent the moisture from evaporating.



Baking yeast is typically a species called Saccharomyces cerevisiae, which is also used to make beer

## Loaf ingredients

**The basic components that work together to create bread**



**Flour**
The flour reacts with water to form gluten and provides the yeast with sugar for energy.

**Salt**
Salt adds flavour to the dough, but adding too much will decrease the activity of the yeast.

**Water**
The water activates the yeast and helps to link together flour proteins to form gluten.

**Yeast**
The yeast feeds on sugar to produce carbon dioxide, which gives the bread a light and airy texture.

## Making bread with science

**A step-by-step guide to harnessing the power of yeast for a light, fluffy texture**

### Mix the ingredients

Put flour, yeast, salt and water into a bowl and mix together to form dough. The flour contains proteins called glutenin and gliadin, which, when combined with water, link together to form gluten. The gluten is what gives the dough its stretchy, elastic properties and the finished loaf its slightly chewy texture.

### Start kneading

Place the dough on a flour-covered surface and press it with the palm of your hand before folding it over, turning it 90 degrees and then repeating the process again and again. This helps form the gluten by making sure the flour and water are mixed together thoroughly. You can stop kneading when the dough has a smooth, elastic surface.

### Let it rise

Place the dough in a clean bowl, cover it with a tea towel, cling film or airtight plastic bag and leave it in a warm place. The yeast – a single-celled living organism – feeds on sugars in the flour and produces carbon dioxide as waste. The carbon dioxide gas gets trapped in the dough's gluten structure and forms bubbles, causing the dough to rise.

### Knock back the dough

Once the dough has doubled in size, take it out of the bowl and gently knead it again. This will knock out some of the air to get rid of any large bubbles in the dough and ensure the smaller bubbles are distributed evenly throughout. Now leave the dough to double in size again, so the yeast can continue to work.

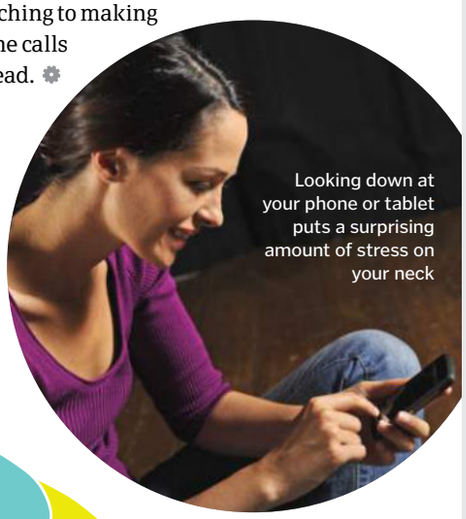
### Bake in the oven

In the oven, heat speeds up the yeast's activity and causes the gases to expand, creating more bubbles and increasing their size. Eventually the yeast dies and the gluten and starch solidify so that the dough can't expand any further. This leaves a light and fluffy centre, while the sugars at the surface caramelise to form a brown crust.

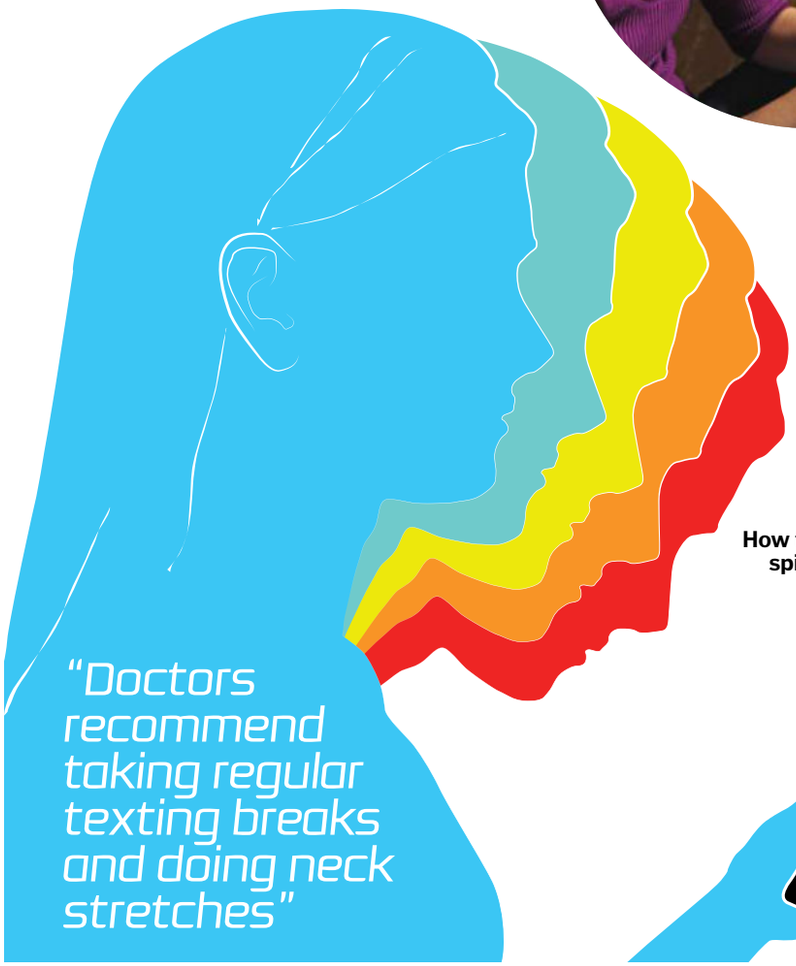
# Could you have 'text neck' syndrome?

## How staring at a smartphone can affect your spine

Whether you're trying to get to the next level of Angry Birds, or having an emoji-filled text conversation with your friends, looking at your smartphone for long periods of time could be doing serious damage to your neck. As we tend to hold our phones at chest or waist height, we tilt our heads forward to be able to see the screen. This isn't so bad if you're just checking the occasional message or weather update, but with smartphone users spending an estimated two to four hours a day looking down at their phones – equivalent to one or two months a year – the problem gets much worse. The average human head weighs around 5.4 kilograms (12 pounds), but when it is angled downwards, the effective weight applied to your spine increases. This can put an enormous amount of stress on your neck, shortening and tightening the muscles and compressing the nerves to cause intense pain and spasms. Doctors recommend taking regular texting breaks and doing neck stretches, or even switching to making phone calls instead.



Looking down at your phone or tablet puts a surprising amount of stress on your neck



"Doctors recommend taking regular texting breaks and doing neck stretches"

### Pain in the neck

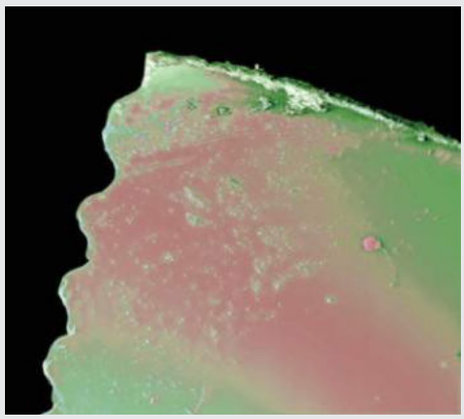
**How the weight on your spine changes as you tilt your head**

| Tilt angle | 0 degrees | 15 degrees | 30 degrees | 45 degrees | 60 degrees |
|---|---|---|---|---|---|
| Weight applied to spine | 5.4kg (12lb) | 12.2kg (27lb) | 18.1kg (40lb) | 22.2kg (49lb) | 27.2kg (60lb) |

# How does sticky tape work?

## Discover the hidden physics that makes gift-wrapping possible

The adhesive on sticky tape is a viscoelastic material, meaning that it behaves both like a solid and a liquid. When you apply pressure to it, it flows like a liquid, finding its way into any tiny gaps in the surface it is being stuck to. Then, when you leave it alone, it turns back into a solid, allowing it to lock into those gaps like a piece of a jigsaw puzzle to hold itself in place. However, before you even apply any pressure, another force has already got to work. The molecules of the adhesive are dipoles, meaning they have one positively charged side and one negatively charged side. This makes the molecules act like tiny magnets, creating an electrostatic attraction when they come into contact with another surface. These weak sticking bonds are known as van der Waals forces, which are also used by geckos to stick to walls. When you peel off the tape, this bond is broken, but will continue to work again and again until the adhesive surface gets too clogged up with dust and dirt.



A scanning electron micrograph of the adhesive side of sticky tape

# How do fireworks make shapes?

## The chemistry behind the spectacular patterns in the sky

Modern fireworks can burst into hearts, smiley faces and even a representation of the planet Saturn. The shape comes down to the construction of the firework's shell (container) and the arrangement of the exploding stars (pyrotechnic pellets) within them. As aerial shells are often spherical, they tend to explode symmetrically. Arranging the stars into the desired shape on a piece of card within the shell makes them explode outwards in that pattern.

Manufacturers also use multi-break shells that have different compartments inside them, often with stars of various colours and compositions. When these are placed and fused in a specific order, they will explode in sequence to create recognisable patterns and shapes in the sky. However, it's not an exact science; many displays will fire several copies of the same firework at the same time so that at least one of them creates the desired shape in the audience's line of sight.

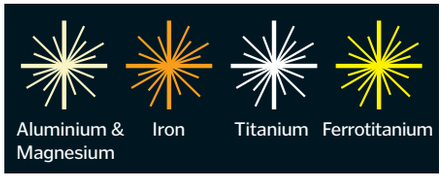
The first shaped fireworks appeared in the early 1990s to welcome returning American troops

## Sparkler science

The chemical composition of sparklers consists of three important components: an oxidiser, a binder and a metal fuel. These three substances are bound together in a paste, which is then coated onto the iron wire that forms the sparkler's main body.

A powdered metal is essential, as it helps produce sparks that generate the famous glittery effect and can also colour the sparkler. Aluminium, titanium and magnesium all produce bright, white sparks, whereas iron will burn with a characteristic orange hue. When iron and titanium are combined they form an alloy called ferrotitanium, which produces golden yellow sparks when it burns.

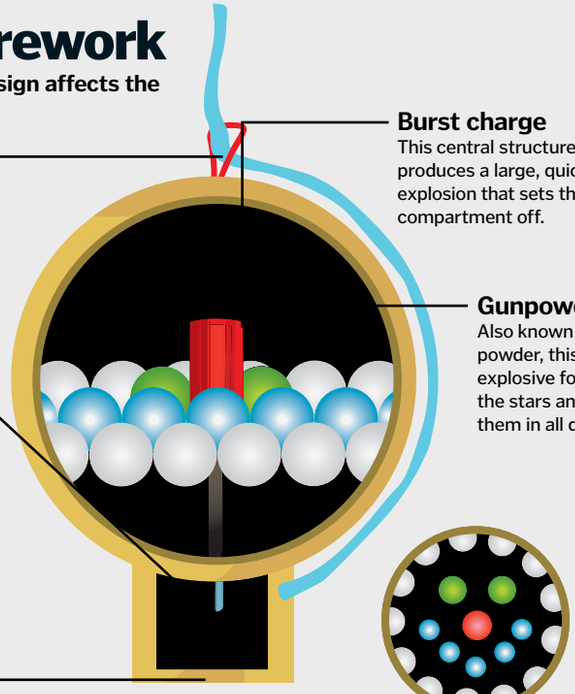
For even more colours, salts of various metals can be added to sparklers, which is often the technique used for creating coloured fireworks. Copper salts produce green-blue, barium salts create green and strontium salts produce red.




Powdered metals react with oxygen to produce metal oxides, which burn with specific colours

## Inside a firework

**See how the internal design affects the shape of the explosion**



**Fuse**
This initial fuse ignites other, smaller fuses within the firework. In public displays, these are lit by electrical contacts called wirebridge fuseheads.

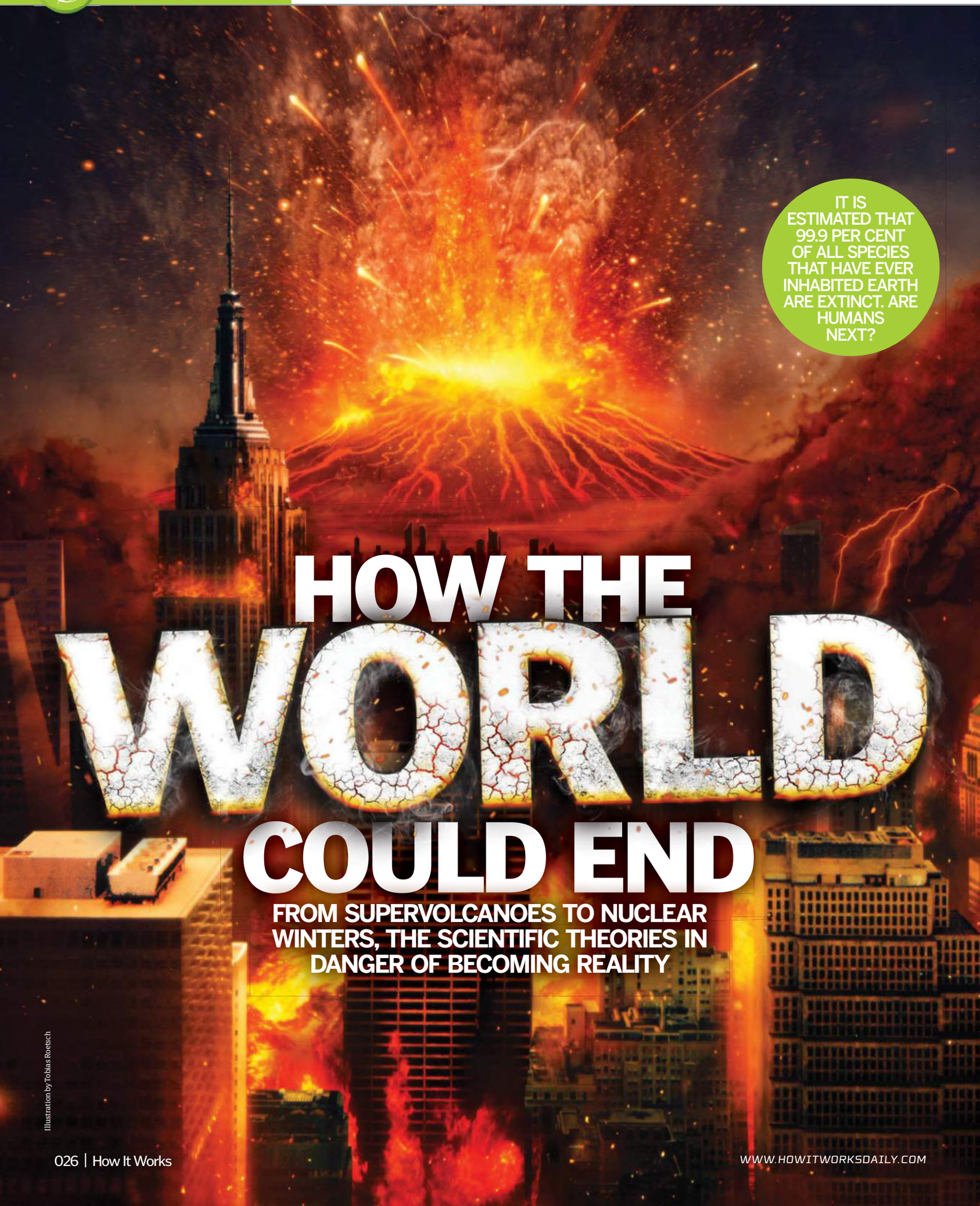
**Burst charge**
This central structure produces a large, quick explosion that sets the entire compartment off.

**Gunpowder**
Also known as black powder, this provides the explosive force that ignites the stars and launches them in all directions.

**Timed fuse**
This section ignites the burst charge once the firework has reached the appropriate altitude.

**Lifting charge**
The initial explosion sends the shell soaring into the air without detonating the main compartment.

**Star arrangement**
Different chemicals are added to create a range of colours, while the shape is determined by the arrangement of small, combustible pellets.



IT IS ESTIMATED THAT 99.9 PER CENT OF ALL SPECIES THAT HAVE EVER INHABITED EARTH ARE EXTINCT. ARE HUMANS NEXT?

# HOW THE WORLD COULD END

## FROM SUPERVOLCANOES TO NUCLEAR WINTERS, THE SCIENTIFIC THEORIES IN DANGER OF BECOMING REALITY

Illustration by Tobias Roetsch

# A SUPERVOLCANO BLOWS

## A cataclysmic eruption plunges the planet into a brutal volcanic winter

Supervolcanoes are the leviathans of volcanism. Defined by their ability to blast more than 1,000 cubic kilometres (240 cubic miles) of material into the air, they are a thousand times larger than the 1980 Mount Saint Helens eruption – the most destructive volcanic eruption in recorded US history.

Geologists have never witnessed a supervolcanic eruption, but by looking at remnants of previous cataclysms, they can piece together alarming details. These eruptions rain debris and fiery destruction on a geographical region as large as Europe, but it's the gases they inject into the stratosphere that could spell disaster for humanity.

During a super-eruption, a scalding plume of gas would belch almost to the edge of space. Levelling off, it would spread out around the globe, forming a veil of sulphate aerosols that would persist for several years and trigger a volcanic winter.

The veil would reflect and absorb incoming solar radiation, warming the upper atmosphere and preventing heat from reaching the surface. The result would be extreme instability in the climate system. Surface temperatures would tumble rapidly, leading to agricultural collapse and famine. Some even speculate that these conditions could lead to the onset of an ice age.

Such catastrophic super-eruptions are rare; the last we know of occurred 27,000 years ago in New Zealand. But they are inevitable. Critically, we have no idea when the next one will strike and absolutely no way to prevent it.

### Volcanic winter

**Global climate in the aftermath of a supervolcanic eruption**

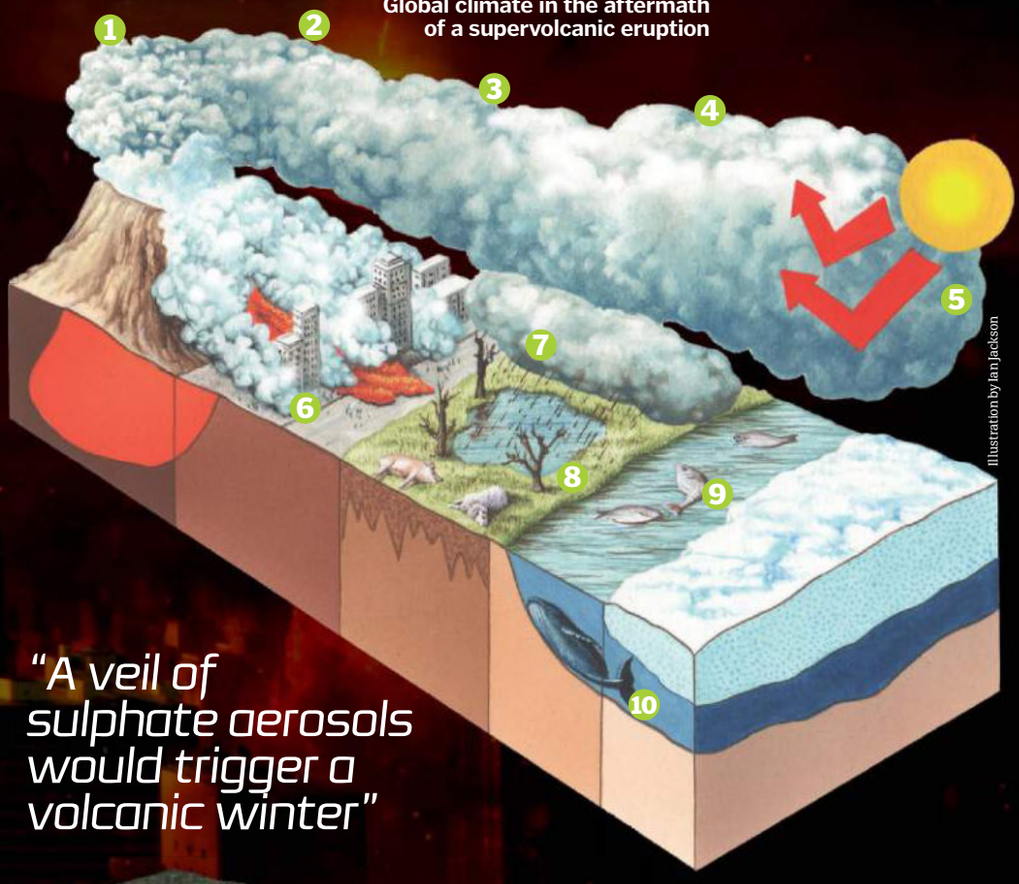



Illustration by Ian Jackson

**1 Ash cloud**
Suspended ash blocks the Sun for several weeks and all air traffic – including aid to the region – is disrupted.

**2 Increased cloud formation**
Sulphate aerosols also act as cloud condensation nuclei, encouraging thicker cloud formation and further blocking of sunlight.

**3 Stratospheric warming**
Incoming sunlight is reflected and absorbed, warming the upper atmosphere and affecting air circulation and weather patterns.

**4 Ozone depletion**
Chlorine, bromine and other aerosols interfere with atmospheric chemistry, encouraging depletion of the ozone layer.

**5 Aerosol veil**
Sulphate particles disperse widely, blocking sunlight for years and causing surface temperatures to plummet.

*"A veil of sulphate aerosols would trigger a volcanic winter"*

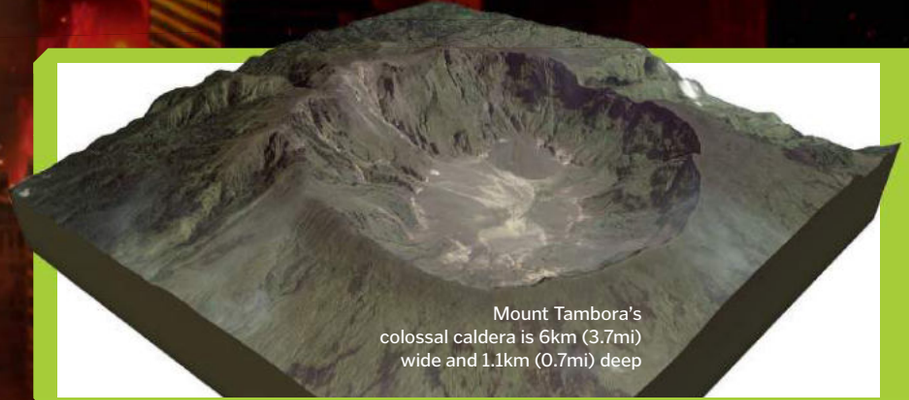
**6 Fallout**
Ash and rubble buries homes, roads, power grids, sanitation systems and agricultural land; famine and disease rage.

**7 Acid rain**
Sulphate aerosols combine with water and fall as acid rain, stripping vegetation and poisoning soils, acidifying lakes, damaging structures and causing respiratory irritation.

**8 Vegetation dies**
Buried by ash, ravaged by acid rain, or strangled by freezing summer temperatures, crops fail, livestock dies, causing widespread famine.

**9 Oceanic circulation chaos**
Reduced sea surface temperatures scramble normal oceanic circulation, altering global weather patterns in unpredictable ways.

**10 Marine biology collapse**
Disturbed circulation and reduced deep-water upwelling hampers nutrient flow, threatening the entire oceanic food chain.



Mount Tambora's colossal caldera is 6km (3.7mi) wide and 1.1km (0.7mi) deep

## Mount Tambora and the year without summer

In 1815, Mount Tambora on the Indonesian island of Sumbawa erupted, ejecting 50 cubic kilometres (12 cubic miles) of material skywards in one of the most powerful eruptions in recorded history.

Tambora claimed an estimated 70,000 lives in the region, and caused climate mayhem across the Northern Hemisphere. Dubbed "the year without a summer", 1816 saw June snowfall in New York and widespread crop failure, famine, disease and riots, bringing the death toll to several hundred thousand. Despite its far-reaching consequences, Tambora was at least ten times smaller than a supervolcano.


# NUCLEAR WINTER

## The smouldering aftermath of nuclear conflict blacks out the Sun

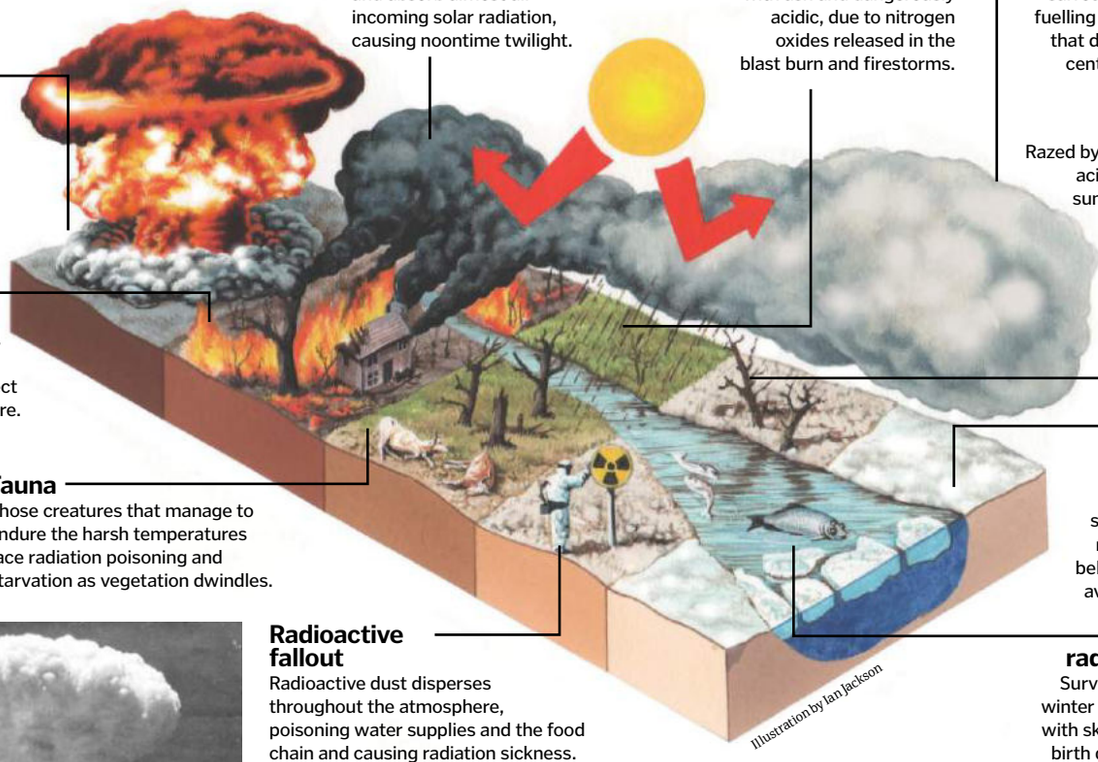
With the power to demolish entire cities in seconds, nuclear bombs are the most devastating weapons on the planet. In many ways, those annihilated in the first moments of a blast could be considered the lucky ones.

In the 1980s, prominent scientists including Carl Sagan warned that a nuclear war between the US and the Soviet Union could drive the globe into a catastrophic nuclear winter. Incinerated cities and forests would send heaving clouds of Sun-blocking ash into the stratosphere – it could take years for particles to be rained out.

In a worst-case scenario, it is theorised that 99 per cent of the Sun's light would be blocked for several months, resulting in noontime twilight and the halting of photosynthesis. Surface temperatures could plummet tens of degrees below normal levels for years or even decades, bringing crippling arctic conditions to the entire globe. Plants, animals and humans would perish in the darkness.

## Nuclear winter

**How nuclear conflict could wreak havoc on global climate and the environment**



**Blast damage**
Everything close to the epicentre is vaporised; damage further afield is caused by a rapidly expanding fireball and pressure wave.

**Nuclear firestorms**
Raging for weeks, firestorms produce billowing black pyrocumulus clouds that inject ash into the upper atmosphere.

**Fauna**
Those creatures that manage to endure the harsh temperatures face radiation poisoning and starvation as vegetation dwindles.

**Ash cloud**
Clouds of ash spread out and absorb almost all incoming solar radiation, causing noontime twilight.

**Black rain**
For months, rains are black with ash and dangerously acidic, due to nitrogen oxides released in the blast burn and firestorms.

**Ozone depletion**
Hot ash warms the surrounding atmosphere, fuelling chemical reactions that destroy up to 70 per cent of the ozone layer.

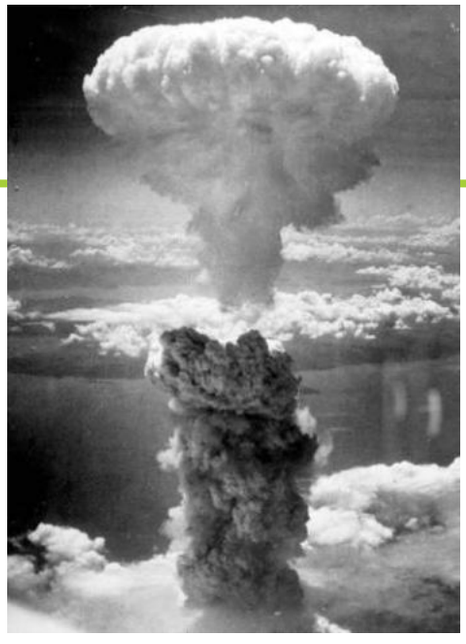
**Vegetation**
Razed by blasts, stripped by acid rain or starved of sunlight, plants die off en masse, causing agricultural collapse and global famine.

**Surface temperature**
Average temperatures drop suddenly for several months and remain below the pre-nuclear average for decades.

**Radioactive fallout**
Radioactive dust disperses throughout the atmosphere, poisoning water supplies and the food chain and causing radiation sickness.

**Long-term radiation effects**
Survivors of the nuclear winter face a bleak future, with skyrocketing rates of birth defects and cancer.

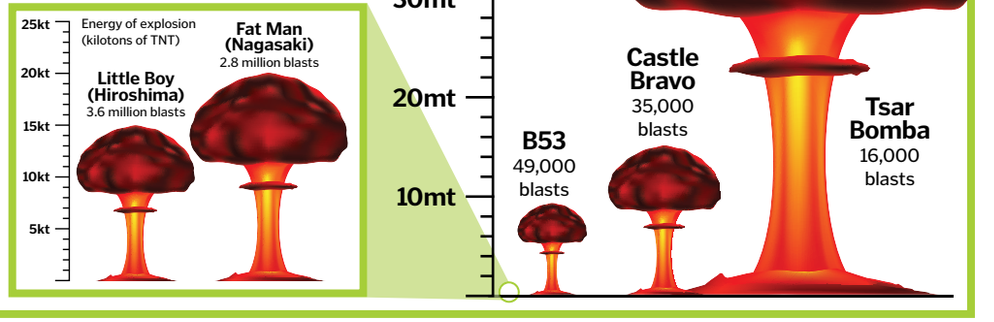
Illustration by Ian Jackson



The mushroom cloud of the 'Fat Man' bomb after it detonated in Nagasaki, Japan, instantly killing around 80,000 people

## How many nukes would destroy Earth?

**How the world's most famous nuclear bombs stack up**



# ASTEROID IMPACT

## A celestial wrecking ball smashes into Earth

Asteroids are hunks of rocky space debris, left over from the creation of the planets, which whizz around our Solar System, orbiting the Sun. From time to time they cross paths with us and, while impacts on the scale of the infamous ten-kilometre (6.2-mile) dinosaur-destroyer are rare, an asteroid a fifth the size could spell disaster for civilisation.

With energy greater than 10 million Hiroshima bombs, the impact shock would flatten everything within a 300-kilometre (186-mile) radius. Dust and debris would cause an 'impact winter' and most living things would perish. An ocean strike would trigger monumental tsunamis, obliterate entire coastlines, and inject seawater into the atmosphere – destroying huge swathes of the ozone layer and exposing survivors to devastating levels of UV radiation.

### Five ways to head off an asteroid

**Given enough forewarning, there are a few tricks that might successfully avert a collision**

**1 Pull it**
Position a 'gravity tractor' 250m (820ft) from the surface; the spacecraft's gravitational pull would gradually tease the asteroid onto a new path.

**2 Slam into it**
Smash a fast-moving spaceship into it, altering its velocity by a sliver and eventually creating a significant path drift.

**3 Push it**
Land an ion-drive rocket engine on the surface, and build up enough thrust to nudge it off course.

**4 Nuke it**
Detonate a nuclear bomb nearby; vaporising surface material would deflect the asteroid's course.

**5 Blow it up**
Bury a thermonuclear bomb deep beneath its surface, detonate, and hope none of the fragments head our way.

### Did an asteroid cause the K/T extinction?

Famous for the demise of the dinosaurs (and 80 per cent of all animal species), the K/T extinction event occurred about 66 million years ago. Scientists' theories that a gigantic space rock was to blame are strongly supported by the existence of a 180-kilometre (112-mile) impact crater – dated as 66 million years old – at Chicxulub in Mexico.

# RUNAWAY GREENHOUSE EFFECT

## Human activities set in motion an unstoppable warming of the planet

The greenhouse effect is essential to life as we know it. Just like a glass greenhouse lets in light but traps heat, insulating gases in our atmosphere protect us from the deathly cold of space.

But since the Industrial Revolution, humans have upset the delicate balance of the atmosphere. Concentrations of carbon dioxide ($CO_2$), released when fossil fuels are burned, and other 'greenhouse gases', have risen at an alarming rate, forming a thick blanket around Earth, trapping excess heat and nudging global temperatures upwards.

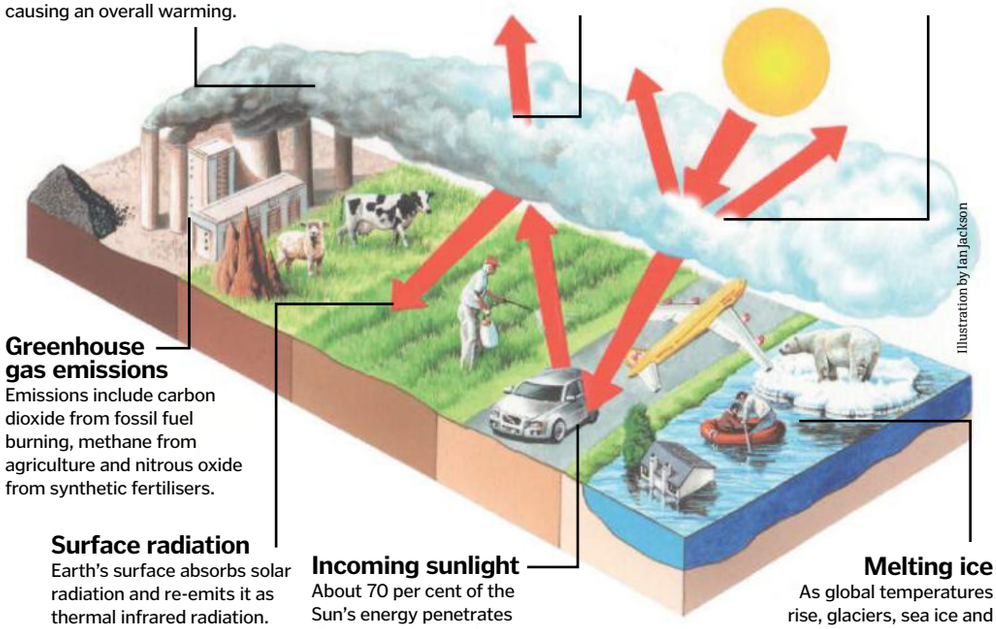
While warmer weather might be welcome in some places, 'feedback loops' complicate the effects of higher temperatures. Increased evaporation will cause denser cloud cover, exacerbating the warming effect because clouds themselves are strong insulators. Longstanding carbon 'sinks' – rocks and oceans that pull $CO_2$ out of the atmosphere – will become unstable and release their stores, accelerating the problem still further.

Scientists warn of a tipping point – a temperature beyond which the problem can no longer be dialled back. If we reach this point, a runaway greenhouse effect would cause temperatures to soar to several hundred degrees Celsius, boiling the oceans and making life on Earth impossible.

**Absorption**
Greenhouse gases absorb outgoing infrared and reradiate some of it back towards Earth, trapping heat in the lower atmosphere and causing an overall warming.

**Outgoing infrared**
Some of the outgoing infrared energy is absorbed by the atmosphere and reflected back down towards the surface, while the rest is radiated into space.

**Reflection**
About 30 per cent of incoming radiation is scattered by the atmosphere or reflected by clouds back out to space.



**Greenhouse gas emissions**
Emissions include carbon dioxide from fossil fuel burning, methane from agriculture and nitrous oxide from synthetic fertilisers.

**Surface radiation**
Earth's surface absorbs solar radiation and re-emits it as thermal infrared radiation.

**Incoming sunlight**
About 70 per cent of the Sun's energy penetrates the atmosphere and heats Earth's surface.

**Melting ice**
As global temperatures rise, glaciers, sea ice and ice sheets melt, causing sea levels to rise.

Illustration by Ian Jackson

# THE SUN DIES

## In its twilight years, our local star turns on us

The Sun supplies the energy for almost all of life on Earth, but all good things come to an end. When the Sun's time comes and it starts to run out of fuel, its core will collapse as the outward force – due to fusion – can no longer balance the strong inward force of gravity. At the same time, its outer envelope will inflate, expanding the star into a red giant, and engulfing the orbits of Mercury, Venus, and – potentially – Earth.

Eventually, the dying Sun will transform into a dense white dwarf surrounded by a dazzling planetary nebula. Humans won't be around to see this; the Sun's fuel supply will start to run low about five billion years from now, but Earth will be inhospitable long before.

## Planet-gobbling star caught in the act

In 2012, astronomers stumbled upon a planet murder in progress. They found that red giant star BD+48 740 currently contains unexpected levels of lithium. This rare element is easily destroyed in stars, indicating that it has recently digested something with the mass and composition of a planet.

A swallowed planet is vaporised and its material blends into the star

## Red giant Sun

**The view from Earth as the Sun grows old**

### Plants disappear

As the climate warms, carbonate rock formation – which sucks $CO_2$ from the atmosphere – speeds up. Although this temporarily stunts overall warming, eventually there is no longer enough $CO_2$ for plants to photosynthesise. All animal life is doomed.

### Temperature rises

As it ploughs through its fuel reserves, the Sun gets about ten per cent brighter – and therefore hotter – every billion years. The increase makes Earth inhospitable to all life in under a billion years.

### Red giant approaches

Billions of years after Earthly life is obliterated, the Sun will begin its red giant phase, swallowing Mercury and Venus and bearing down on our now barren rock.

### Earth's fiery demise

Although some experts suggest that the Sun's reducing gravitational pull will allow Earth's orbit to spiral outwards to safety, most agree that it will be devoured and vaporised.

### Oceans evaporate

Soaring temperatures cause the oceans to boil. The atmosphere fills with water vapour and the surface turns into a desert. Without water, all but the hardiest microbes die off.

Sun

Mercury
0.38 AU

Venus
0.72 AU

Earth
1 AU

Mars
1.52 AU

Today: the Sun is at a distance of one astronomical unit (1 AU) - 150mn km (93mn mi) - from Earth

*"The dying Sun will swallow Mercury, Venus, and – potentially – Earth"*

Mars
1.9 AU

7.5 billion years from now: the Sun has expanded and engulfed the innermost planets

# GAMMA-RAY BURST

## An explosion hundreds of thousands of light years away annihilates the ozone layer

Gamma-ray bursts (GRBs) are the brightest events in the universe. Produced by the explosion of massive stars, they emit focussed beams of intense gamma radiation. They can last anywhere from a fraction of a second to several hours, and can release as much energy in ten seconds as the Sun will produce in its entire lifetime.

If the Earth were unlucky enough to get caught in a GRB's almighty death beam, the effects would be catastrophic. It would trigger atmospheric chemistry that would destroy the ozone layer – leaving life on the surface exposed to deadly ultraviolet radiation.

## Earth in the firing line

According to astronomers, GRBs are triggered close enough to affect life on Earth about once every five million years. Evidence in the tree ring record suggests our latest hit was nearly 1,250 years ago. Tree rings from all over the world show 20 times the normal level of carbon-14 in the year 774, an effect that scientists calculate could have been caused by a GRB about 13,000 light years from Earth.

Some scientists believe that GRBs may also have been responsible for some of the major extinction events that have happened throughout Earth's history, including the Ordovician-Silurian event approximately 440 million years ago, where 60 per cent of marine invertebrate life perished.

GRBs are astronomical showstoppers that briefly shine a million trillion times as bright as the Sun

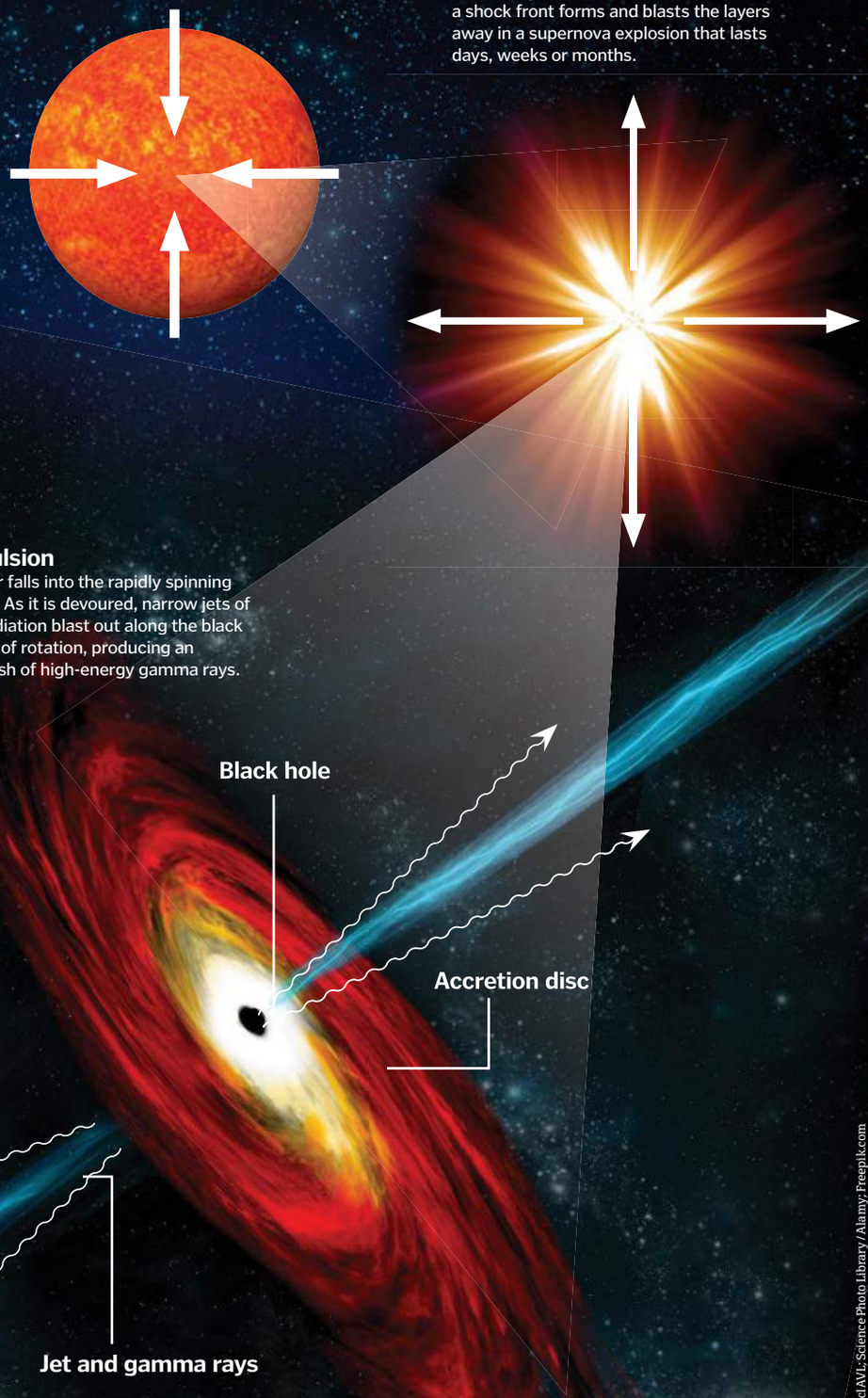
## Anatomy of a long GRB

**Step-by-step guide to the brightest electromagnetic events in the universe**

**1 Star death**
When a massive star's energy dwindles and it nears the end of its life, it swells to become a red giant. When its fuel supply finally runs out, the star collapses under its own gravity, crushing its core into a black hole.

**2 Supernova**
The heat created by the collapse (around 100bn°C/180bn°F) forces particles violently outwards from the core. As these slam into the star's collapsing outer layers, a shock front forms and blasts the layers away in a supernova explosion that lasts days, weeks or months.

**3 Expulsion**
Matter falls into the rapidly spinning black hole. As it is devoured, narrow jets of intense radiation blast out along the black hole's axis of rotation, producing an intense flash of high-energy gamma rays.



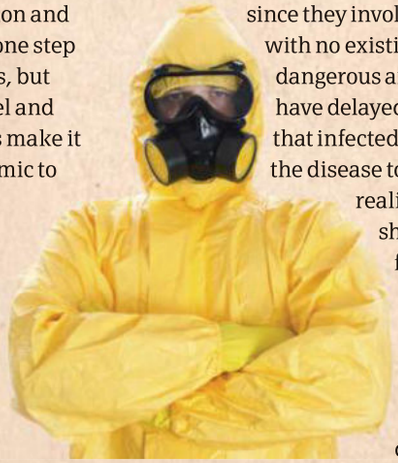
# GLOBAL PANDEMIC

## Infectious disease sweeps the planet, eradicating the entire human race

A pandemic is an outbreak of infectious disease that spreads throughout much of the globe. Human history is punctuated by debilitating pandemics and, despite medical advances, it's only a matter of time before we see another.

Today's standards of sanitation and medical research help us stay one step ahead of most infectious agents, but widespread international travel and increased population densities make it much easier for a global pandemic to threaten us all.

In 2003, SARS (severe acute respiratory syndrome) – a serious form of pneumonia – spread to six of the world's seven continents within months, infecting an estimated 8,000 people and killing 750. More recently, Ebola – a grisly disease ravaging West Africa with a death toll over 11,000 – threatened to go pandemic in late 2014 after cases popped up in travellers arriving back in North America and Europe.



Emerging diseases pose the biggest problem, since they involve unknown pathogens with no existing vaccinations. The most dangerous are highly contagious but have delayed symptom onset, meaning that infected people unwittingly spread the disease to many others before realising they are sick. Shape-shifting diseases that mutate fast are almost impossible to vaccinate against. In today's hyper-mobile, city-dominated world, a deadly disease combining these three features could spell doom for the human race.

### The Black Death

One of the deadliest pandemics in human history, the Black Death was the second plague pandemic. Originating in China in the 1330s, it spread along the Silk Road trade routes to Europe, where it claimed the lives of an estimated 60 per cent of the population. Victims developed high fevers, vomited blood, and usually perished within a week.

Medieval doctors did not know what caused the Black Death, and were unable to stop it spreading

## Outbreak

**The deadliest pandemics in human history**

**BLACK DEATH**
1346-1353
**50 million**
Bu

**MEASLES**
7th century BCE-1963
**200 million**
Fv Rs Co St Re

**SPANISH FLU**
1918-1919
**50-100 million**
Ft Ha Bl Fv Sd Vo

**SMALLPOX**
10,000 BCE-1979
**300 million**
Fv Ha Ft Vo Di Le

*"Shape-shifting diseases that mutate fast are almost impossible to vaccinate against"*

**HIV/AIDS**
1981-present
**39 million**
Fv Ch Bu Wl

**PLAGUE OF JUSTINIAN**
542-546
**100 million**
Fv Sz Bu Ch Sd

**CHOLERA**
1817-present
**Tens of millions**
Di Vo Nu De

| Fever | Chills | Headache | Weight loss | Fatigue | Red eyes | Bleeding | Diarrhoea | Dehydration | Cough | Bubo (lymph node swelling) | Vomiting | Sore throat | Seizures | Skin discolouration | Rash | Lesions | Nausea |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fv | Ch | Ha | Wl | Ft | Re | Bl | Di | De | Co | Bu | Vo | St | Sz | Sd | Rs | Le | Nu |

# ROBOT TAKEOVER

## Artificial intelligence transcends human intelligence and turns on its creators

*I, Robot*, *2001: A Space Odyssey*, the *Terminator* movies; we all know how this goes down. But some computer scientists believe that we're fast approaching a moment known as 'the singularity' – a tipping point where self-aware machines surpass the capabilities of the most intelligent human mind.

Beyond this point, it's impossible to predict how things will pan out. An unchecked superhuman intelligence would be so incomprehensible to us that we would no longer be able to control it, and if it decided to terminate the human race, we would be powerless to stop it.

AI could supersede the human race if appropriate controls aren't built in

### Experts weigh in

You may dismiss public fears about artificial intelligence (AI) as the result of too much sci-fi entertainment. But when prominent thinkers and technologists start expressing concern, it's time to take notice.

Some of the leading minds of our time – including physicist Stephen Hawking, Microsoft co-founder Bill Gates, and engineer and entrepreneur Elon Musk – have spoken out publicly over the last year, warning that the majority of people don't appreciate the speed with which AI technology is advancing and the very real threat it could pose.

Musk and Hawking were also among thousands of AI scientists and tech-savvy thought leaders to sign an open letter calling for a ban on offensive autonomous weapons.

# CHOOSE YOUR OWN APOCALYPSE

## Which of these doomsday scenarios will become a world-ending reality?

Optimists would assure you that humanity will avoid foolish nuclear wars, begin to behave responsibly in response to climate change, get serious about controlling AI, and stay one step ahead of emerging diseases. These things, at least, are feasibly within our control. Beyond that, we are at the mercy of the laws of physics.

Statistically, a supervolcano is most likely to hit first. A devastating super-eruption is thought to occur about once every 100,000 years, whereas world-threatening GRBs and asteroids rear their heads perhaps only once in every 500,000.

In truth, it's likely that a combination of catastrophic events – and a chaotic human response to them – will secure our demise. If they don't – the Sun will be hot on our heels in a billion years' time.

# La Niña explained

## How this Pacific Ocean phenomenon is responsible for weather extremes

La Niña is defined by unusually cold ocean temperatures in the equatorial Pacific. It's caused by a build-up of very cool water in the tropical Pacific, which is brought to the surface by easterly trade winds and ocean currents. This upsurge of water causes sea-surface temperatures in areas near South America to drop drastically.

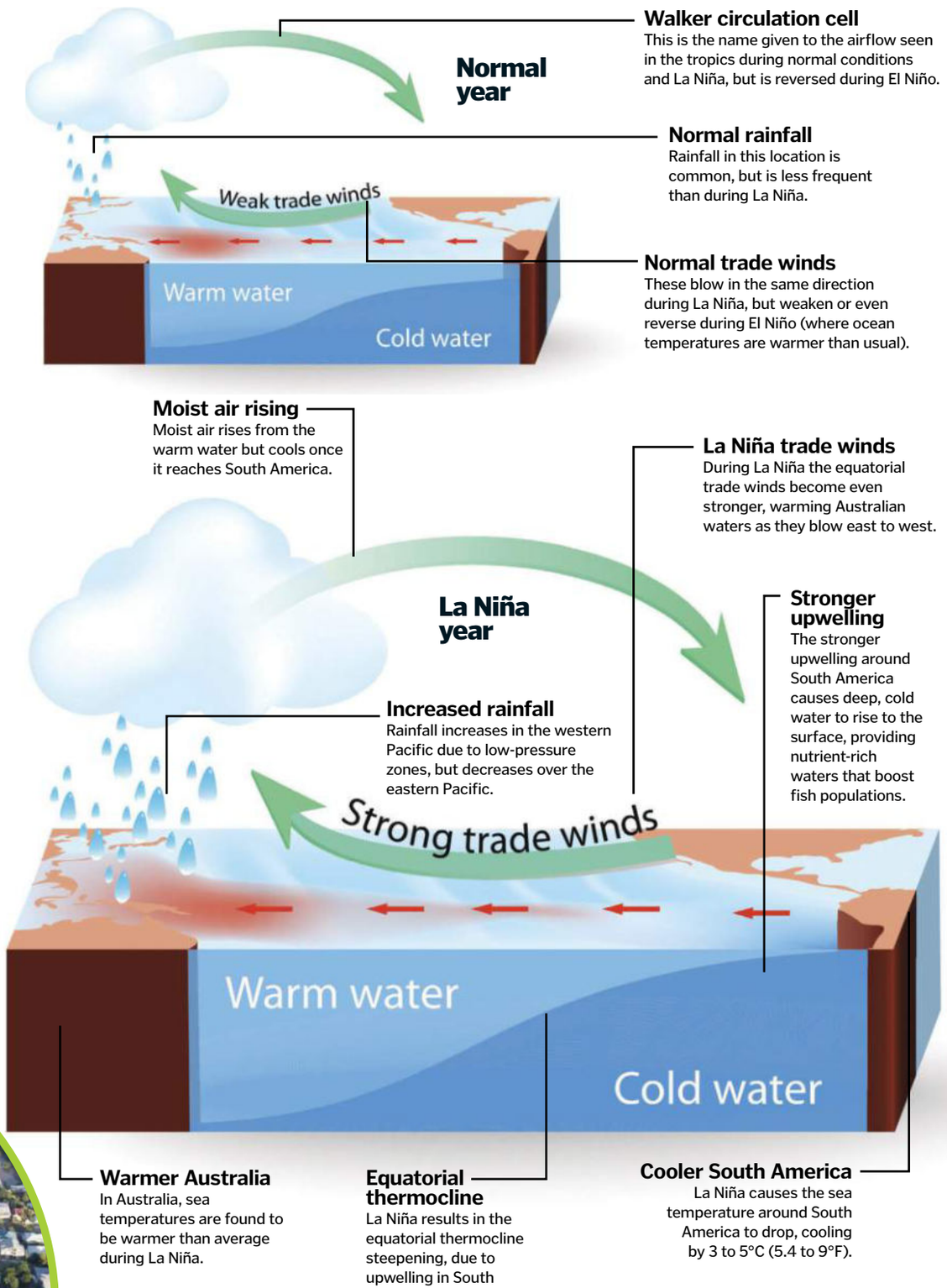
La Niña can trigger changes in rainfall patterns, atmospheric circulation and atmospheric pressure, having dramatic effects on the global climate. La Niña events are associated with cataclysmic flooding in Northern Australia. In 2010, they resulted in arguably the worst flooding in Queensland's history, causing more than two billion Australian dollars' worth of damage and requiring the evacuation of over 10,000 people. La Niña does have some positive effects, however, often boosting the South American fishing industry due to the upwelling of nutrient-rich waters, where fish populations thrive.

Although our understanding of La Niña has grown, forecasting it is still difficult, even when combining the latest satellite and marine buoy data. With such a global impact, every effort is being made to find a way to predict this age-old phenomenon.

The devastation caused by La Niña in Queensland was unprecedented; thousands of homes were destroyed

## What happens during La Niña?

**See how a period of cooler sea temperature can have far-reaching effects**




**Walker circulation cell**
This is the name given to the airflow seen in the tropics during normal conditions and La Niña, but is reversed during El Niño.

**Normal rainfall**
Rainfall in this location is common, but is less frequent than during La Niña.

**Normal trade winds**
These blow in the same direction during La Niña, but weaken or even reverse during El Niño (where ocean temperatures are warmer than usual).

**Moist air rising**
Moist air rises from the warm water but cools once it reaches South America.

**La Niña trade winds**
During La Niña the equatorial trade winds become even stronger, warming Australian waters as they blow east to west.

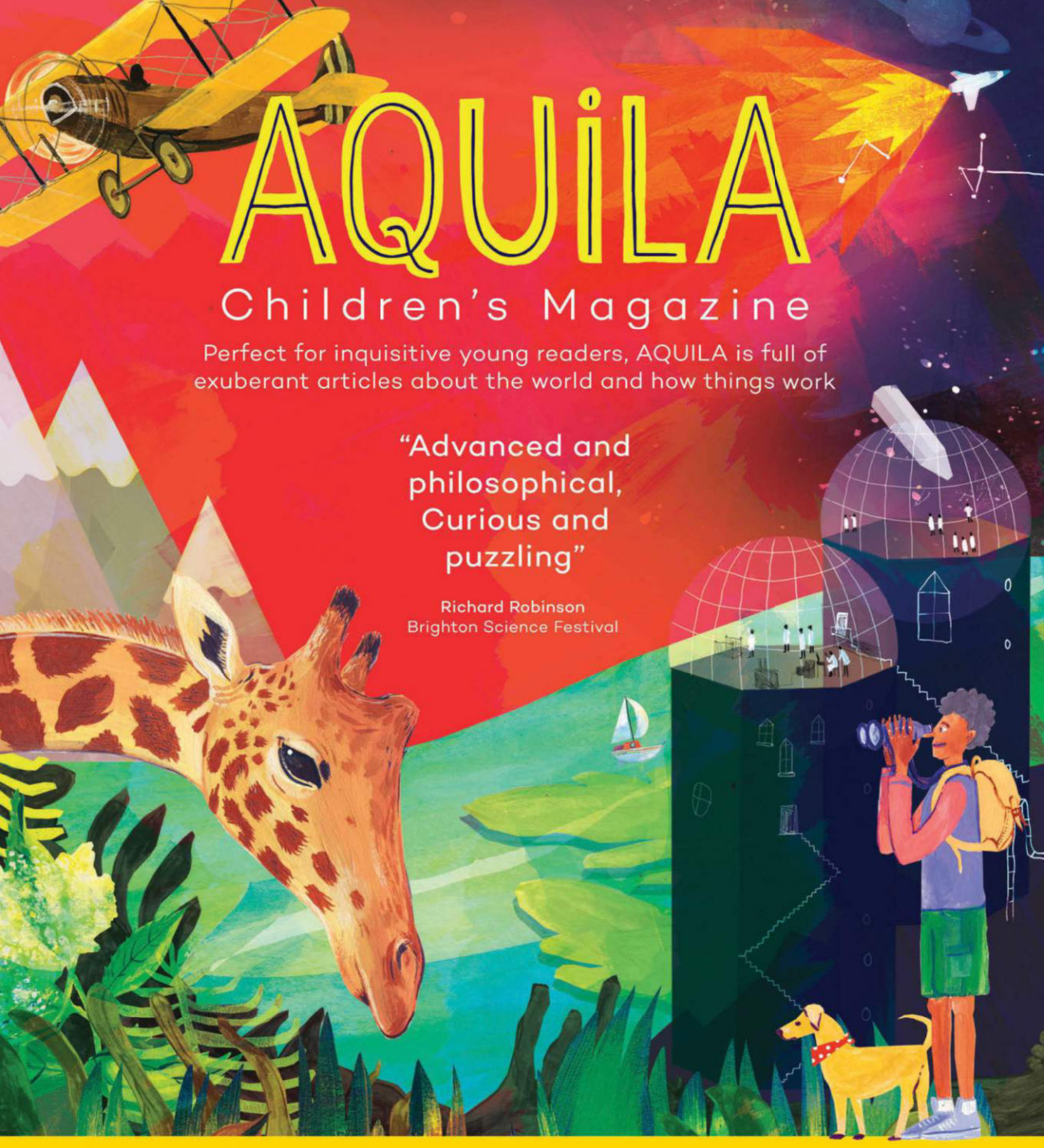
**Stronger upwelling**
The stronger upwelling around South America causes deep, cold water to rise to the surface, providing nutrient-rich waters that boost fish populations.

**Increased rainfall**
Rainfall increases in the western Pacific due to low-pressure zones, but decreases over the eastern Pacific.

**Warmer Australia**
In Australia, sea temperatures are found to be warmer than average during La Niña.

**Equatorial thermocline**
La Niña results in the equatorial thermocline steepening, due to upwelling in South American waters.

**Cooler South America**
La Niña causes the sea temperature around South America to drop, cooling by 3 to 5°C (5.4 to 9°F).

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# Real-life zombie animals

## The human version may be fictional but in the animal kingdom, zombies have no mercy…

*"Gruesome body-snatchers control the animals' minds, using them as living-dead puppets"*

They're not quite the classic brain-eating, gormless slow-shufflers of horror movies, but for some species, the zombie threat is very real. The culprit? Parasites: small organisms with complex life cycles that set up camp inside their animal hosts. These gruesome body-snatchers are able to control the animals' minds, using them as living-dead puppets and steering them to positions of optimal benefit.

One classic case is the zombie ant. The parasite is a mind-controlling fungus (Ophiocordyceps camponoti-rufipedis) that manipulates carpenter worker ants into straying far enough from the colony that their social immunity is impaired. The fungus makes the ant bite down underneath a leaf, where it is anchored until it dies, then the ant's corpse is used by the fungus to grow. The fungus also releases spores that rain down and infect more ants, and so the nightmare continues.

One insect group responsible for zombifying its victims and turning them into mindless drones are wasps. The jewel wasp (Ampulex compressa) injects venom directly into the brains of cockroaches, targeting two specific locations that render the roach's free will useless. The wasp leads the cockroach to a burrow and lays an egg on the roach's abdomen. The zombie roach only dies once the egg hatches and the larva devours it piece by piece.

Another wasp species, the green-eyed wasp (Dinocampus coccinellae), makes light work of harnessing the power of the ladybird. The wasp lays her eggs inside the bug, and new evidence suggests that a virus also attacks the ladybird's brain, paralysing and enslaving it as a zombie babysitter. The larva emerges and weaves a cocoon between the ladybird's legs so the paralysed bug acts as a bodyguard until the larva is ready to leave. Amazingly, a quarter of ladybirds recover from their zombification!

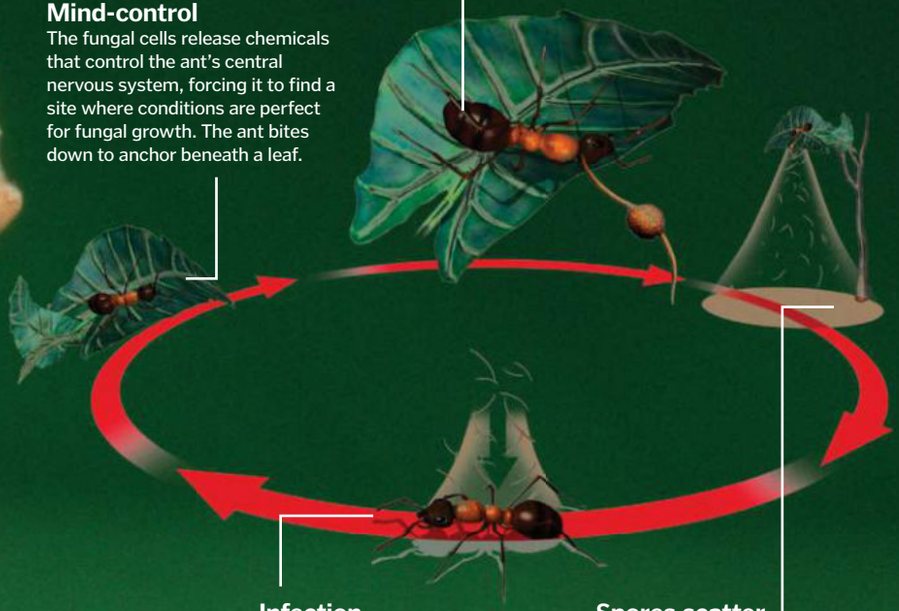
## Rodents of the undead

Animals are biologically hard-wired to fear and flee from their predators. However, one parasite is capable of reversing a rodent's natural fear of felines, and even encourages them to actively seek cats out – leading to their demise by the teeth and claws of a kitty.

Related to the parasite that causes malaria, Toxoplasma gondii is a single-celled pathogen that infects many types of mammal and bird, causing a disease known as toxoplasmosis. Like every life cycle, Toxoplasma has to reproduce, and the only place that this specific microbe can do that is in the gut of a cat. When it infects rodents, Toxoplasma reverses the fear of cats in a rodent's brain, and encourages it to seek out felines by making the rat attracted to the scent of cat urine. Inevitably, this results in the infected rat getting eaten, allowing Toxoplasma to continue its life cycle within the feline hunter.

## The zombie ant

**How a mind-controlling fungus enslaves carpenter ants, one worker at a time**



### Death

The fungus then kills its host and uses the nutrients from the ant's body to grow a large stroma (a spore-releasing stalk). This extends down from the back of the ant's head.

### Mind-control

The fungal cells release chemicals that control the ant's central nervous system, forcing it to find a site where conditions are perfect for fungal growth. The ant bites down to anchor beneath a leaf.

### Infection

As they forage in their woodland home, slightly too far from the colony for social immunity to protect them, worker ants unwittingly get exposed to fungal spores.

### Spores scatter

Once the fungus matures, the spores are given off. The fungus is perfectly placed to shower the forest floor with zombie-making spores to enslave new ants.

## Death-wish fish

Killifish in California have been discovered to play host to a mind-sucking parasite that alters behaviour in order to further its own species. These zombie fish are infected with a fluke, a small, parastitic worm that reproduces in the guts of sea birds. The flukes are able to limit the production of serotonin in the fish's brain, which makes the fish very restless. Ordinarily shy of the surface and its dangers, infected fish actively swim near and even flick the water surface, greatly enhancing the changes of getting plucked out and eaten by a bird.

# CRIME FIGHTING TECH

## THE COOL COP GADGETS THAT ARE WAGING A WAR ON VILLAINY

Throwable robotic cameras and high-speed drones are just a few of the revolutionary crime-fighting technologies on the horizon. The development of this advanced equipment has become crucial to helping police officers investigate and solve cases in the face of severe budget cuts. In the UK alone, the police have had their funds slashed by 20 per cent in the last four years. On top of that, there are now only 43 police forces in the UK compared to 120 in 1946.

Police chiefs around the world are unlikely to be getting more officers or more money in the near future, yet investments in new technology are still being made in almost every department, in the hope that it will improve the speed and accuracy of their work. These innovations hold the key to cutting costs and reducing the need for a physical police presence.

One innovative piece of crime-fighting tech is ShotSpotter, a gunshot detection system that's becoming commonplace in the United States. It's made up of a series of microphones that detect gunfire based on an algorithm. If a shot is fired, an alert is sent to police headquarters.

Officers are also utilising a new type of software in order to predict and prevent crime in their communities. Known as PredPol, it works by using only three bits of data to forecast felonies: the previous types of crime committed in an area, the precise location and the time of day. This software is an invaluable tool for the police branches that use it, helping officers to optimise their time and help stop crime before it happens.

It is believed that just by having a police presence in these identified areas, crimes are less likely to occur. The Los Angeles Police Department has had great success with PredPol so far, and claim to disrupt criminal activity eight to ten times a week as a result.

As criminals become wiser to police practices, smart technology will become paramount. Facial recognition, laser-mapping and secure police apps have all been significant additions to police forces around the world, and are now relied upon extensively.

We aren't close to pre-arresting criminals like Tom Cruise in *Minority Report* or seeing a superhuman cyborg law enforcer in the style of *RoboCop*, but we will see police forces armed with more hi-tech tools in the years to come.

# Future cops

## The gadgets that will make officers safer and smarter

**Graphene protection**
Supermaterial graphene could be used to make tough yet light body armour. It is 200 times stronger than steel but weighs six times less.

**Body camera**
These cameras are already being employed across ten London boroughs, and are hoped to speed up convictions and also identify bad policing.

**Smart watch**
Wearable tech such as smart watches can provide officers with quicker access to intelligence, including photos or tweets posted in their location.

**Smart vest**
Built-in heart rate and blood pressure monitors can alert the emergency services when an officer needs help, and there's even a device that identifies if an officer falls or is knocked over.

**Taser**
Not every officer in the UK carries one but they are commonplace in the United States, stopping suspects by delivering a high-voltage shock.

Illustration by Kevin McGivern

## The real-life RoboCop headset

Golden-i is a new wearable headset that provides police officers with superhuman abilities. The Golden-i gives the wearer access to important information quickly and easily, and is operated by voice commands and head movements, leaving the officer's hands free. It provides real-time situational awareness by accessing nearby CCTV and live video feeds from other headsets in the area.

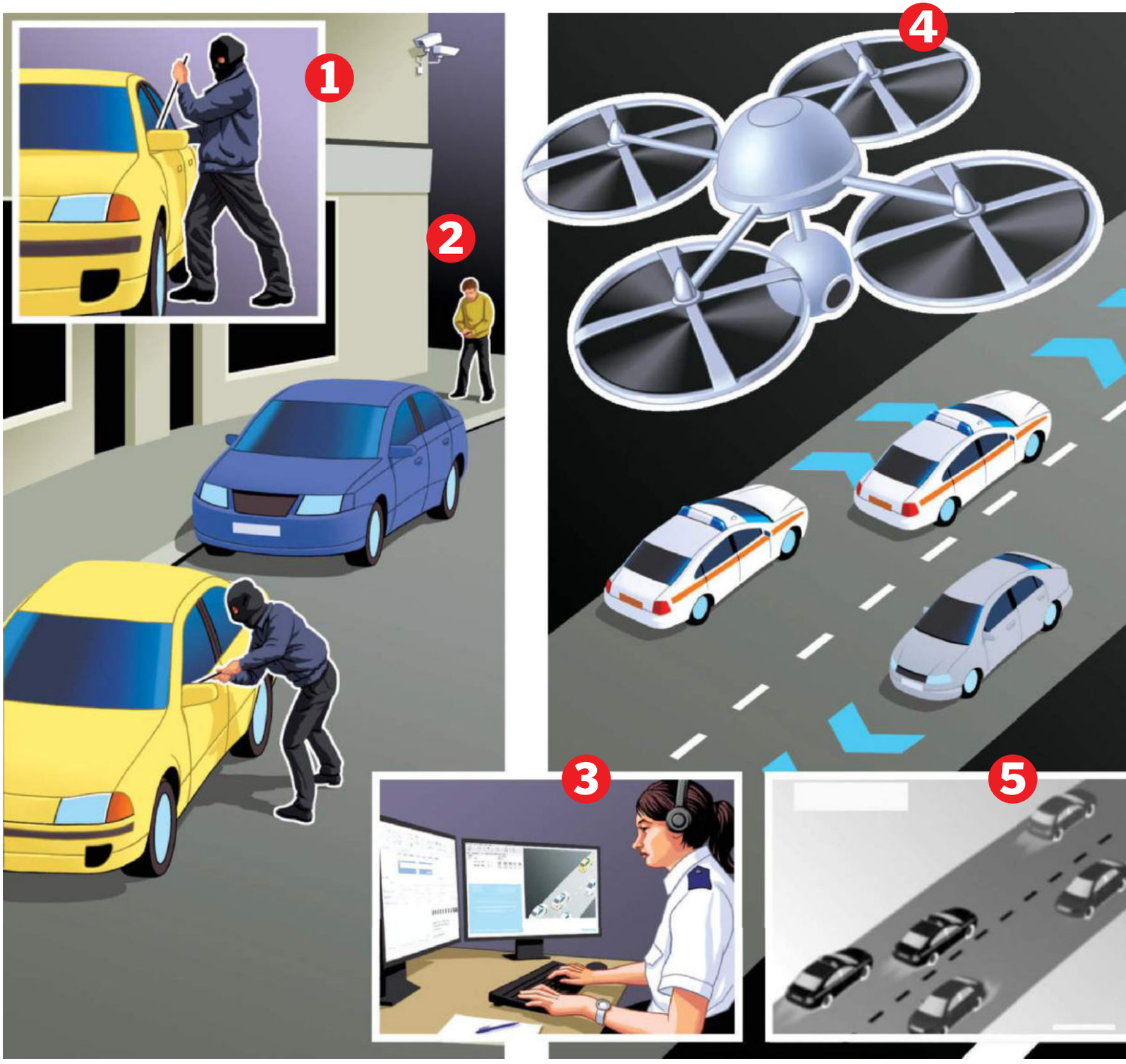
The accompanying Police Pro application has facial recognition software to identify suspects already known to the police, and can call up floor plans and GPS coordinates of places of interest. Most impressive of all is its ability to see through walls using infrared technology, great for finding a hiding suspect when combined with its thermal vision application.

The Golden-i's 14-megapixel camera is inertially stabilised, allowing even a running police officer to record smooth video of a crime in progress. Slightly different versions of Golden-i have also been designed for firefighters and paramedics.


The heat sensor function helps to find hidden suspects when visibility is poor

## The non-lethal laser dazzler

The Dazzler does much more than temporarily blind bad guys: it can also stop them in their tracks. Developed by Intelligent Optical Systems Inc for the Department of Homeland Security in the United States, this flashlight measures the distance to the target's eyes with a range finder, so that it can adjust the strength of the light pulses it fires to ensure that no permanent damage is done. These ultrabright light emitting diodes (LEDs) incapacitate a person in two ways. The flashes cause temporary blindness like any strong light does, but the real innovation lies in the psychophysical effects, ranging from vertigo to disorientation to nausea, typically lasting for a few minutes.




# Catching criminals

See the latest tech in action, and how it can help to make an arrest

**1 CCTV**
It is estimated that there are nearly six million CCTV cameras in Britain – about one camera for every ten people – making it one of the most heavily-surveilled countries in the world. The police have access to all CCTV cameras, and can often find vital video evidence that can be used in court.

**2 Social media**
The relatively recent social media boom has not gone unnoticed by the police. They have their own intricate software that scans all social media channels for key words related to crimes they are investigating, and use it to pinpoint times and locations of specific offences. You'd be amazed at how many people incriminate themselves on Facebook.

**3 Police HQ**
Police headquarters collate all the available information so they can decide on the most appropriate response. They will also receive emergency calls from the general public that they must respond to as quickly as possible, often by requesting a police presence at the area in question.

**4 Drone surveillance**
Police surveillance drones can be controlled remotely by officers, allowing them to follow a fleeing suspect without risking injury to themselves. Modern drones can stream live video either to police cars or headquarters, so that the suspect's location and activity can be monitored in real time.

**5 Thermal imaging**
For police patrolling at night, visibility is always an issue. Thermal-imaging cameras give officers the night-vision edge of a police helicopter, perfect for finding a suspect hiding under the cover of night. Advanced systems can see a full 360 degrees around the vehicle due to their pan and tilt functions.


### 6 OnStar remote deactivation

A new subscription service called OnStar has the ability to track your car if it's stolen, and can even remotely disable the vehicle by shutting down its engine. This was used recently in the United States to catch a car thief. The police hope that it will reduce the need for high-speed police chases in the future, which are often very dangerous and costly.

### 7 GPS dart

The GPS dart system is a new concept for police cars around the world. This laser targeting device fires a small, mobile phone-sized GPS tracker, which sticks to cars thanks to its strong adhesive coating. This enables the police to remotely monitor the vehicle's route, and plan how they want to apprehend the suspect.

### 8 Licence plate cameras

Automated licence plate scanners are being fitted to more and more police cars. They record licence plate information for every car they see (they can scan thousands of plates per hour) and feed this into the onboard computer to see if any of the cars are of interest to the police.

### 9 Super sirens

The need for improved sirens has prompted many police forces to try a new, more powerful siren system, which can alert drivers that are playing loud music in their own vehicles. Large woofers by the wheels produce a deeper sound that can be heard up to 61 metres (200 feet) away.

### 10 Hi-tech handcuffs

Although somewhat sinister, hi-tech handcuffs are being pushed for by many police forces. Unlike the simple steel restraints currently available, they have the ability to deliver taser-like shocks to prisoners if they fail to comply with police orders or suddenly become aggressive.

Illustration by Tom Connell

# K5 crime-fighting robot

**Will this Dalek-like machine change the way our cities are policed?**

Meet the Knightscope K5, the world's first security 'bot that its inventors believe can cut crime by 50 per cent in the areas it patrols. The K5 stands at just over 1.5 metres (five feet) tall and is fitted with an array of technology, from number plate recognition to thermal imaging. It even has odour detectors that can monitor pollution.

The K5 is designed to be fully autonomous, patrolling and charging itself without any human involvement. In spite of its ominous appearance it is not weaponised, mainly working towards crime prevention and serving as an extra source of intelligence for the police. The K5 will initially be used as part of campus security, either for universities or businesses that occupy large sites. However, there is no reason why these clever robots won't eventually make their way onto our streets.

**LIDAR**
The K5 can measure distance and 3D-map areas by illuminating a target with a laser and then analysing the reflected light, a technology known as Light Image Detection and Ranging (LIDAR).

**Emergency button**
An emergency button on the K5 allows passers-by to push and talk immediately to the emergency services.

**Multi-directional imaging**
Its high definition, 360-degree camera allows the K5 to capture video in all directions.

**Sensitive microphones**
By using its audio event detection software, the K5 identifies significant sounds such as horns honking and glass smashing, which it can then investigate further.

**Character recognition**
By scanning the images its camera takes and converting the text into code, the K5 can search a defined database for key crime terms.

**Powerful lights**
30 LEDs and six infrared lights give the K5 excellent illumination, helping it see clearly in poor light.

**Accurate GPS**
The K5's GPS is accurate to 2.5 metres (8.2 feet) and can be detected in less than one second.

# Crime scene drones

Few would argue with the fact that understanding the crime scene is key to solving any offence. This usually requires a crime scene investigator to take extensive photographs, which can be a lengthy process that risks contamination and even the destruction of evidence. By sending in a drone, however, the entire scene can be photographed without disturbance in just 15 minutes.

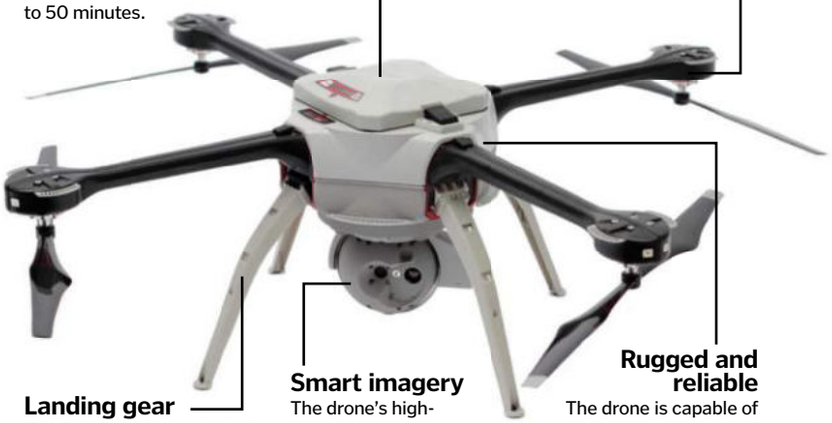
These images can then be used to build up a three-dimensional model of the scene, which can be examined back at police headquarters immediately and even submitted in court as evidence. High-resolution photography of fingerprints can be quickly uploaded to databases and compared with police records. This could potentially identify a criminal without officers having to step foot onto the scene.

A drone can also capture video, quickly identifying points of interest that crime scene investigators can examine further. Dangerous crime scenes that forensic teams wouldn't dare enter become accessible, and these autonomous machines can fly in and detail the evidence before it is damaged further by any adverse building conditions.

However, as much as drones can provide an invaluable crime-fighting service, their use must be carefully monitored to avoid invasions of privacy and general misuse. Weaponised police drones won't be permitted in many parts of the world, although there has been a law passed in North Dakota in the United States to allow police to fire tasers from drones. The potential uses of drones are vast, but we are yet to see how much the police will utilise them.

## Aeryon SkyRanger

**Find out why the Aeryon SkyRanger is the go-to drone for police around the world**



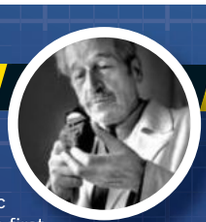
**Power plant**
The top-mounted battery unit powers four motors, allowing the drone to fly continuously for up to 50 minutes.

**Airborne in seconds**
Its folding design allows the drone to be stored in a backpack when not in use, and can be quickly prepared for flight without the need for extra assembly.

**Landing gear**
The four flexible legs help the drone survive hard landings, protecting the camera and electronics from damage.

**Smart imagery**
The drone's high-resolution camera can stream HD video to police headquarters and capture 15-megapixel still images.

**Rugged and reliable**
The drone is capable of withstanding winds of 65km/h (40mph) and temperatures of -33 to 50°C (-27.4 to 122°F).



**1901**
Human blood grouping (ABO) is discovered by Karl Landsteiner. This system is later adopted for use on crime scene bloodstain analysis.

**1910**
Edmond Locard, a pioneer of forensic science, opens the first official police crime lab in Lyon, France.

**1930s**
Cars and motorbikes start to be used regularly by the police.

**1932**
The FBI establishes its Technical Laboratory, providing forensic support.

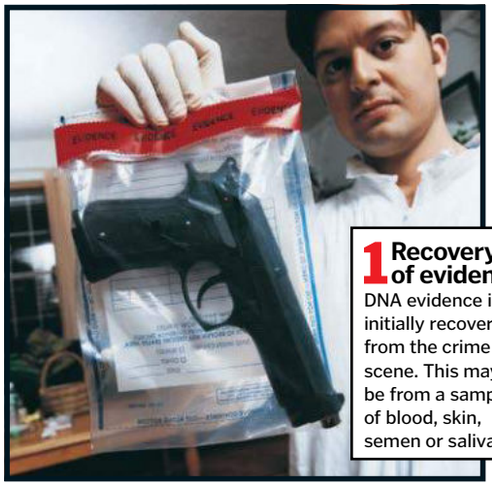
**1960s**
Auditory analysis is used to identify speakers from recordings by comparing their 'voiceprints'.

# Snapshot facial reconstruction

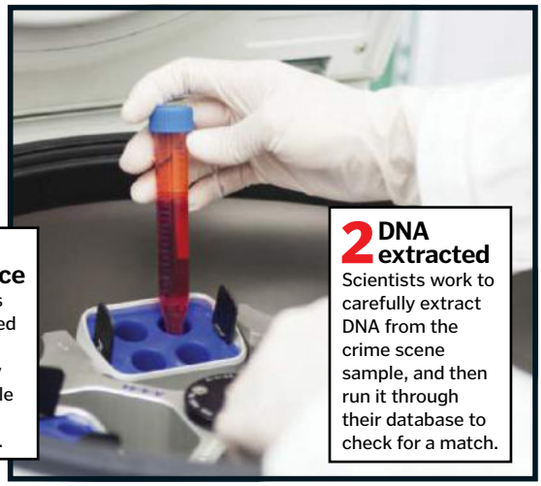
## This incredible system can create a face from nothing more than genetic code


Samples of DNA found at a crime scene can be used to establish a rough idea of the perpetrator's appearance

Various methods for facial reconstruction have existed for decades, but none are as impressive as Snapshot DNA phenotyping. This technique can be used in the absence of photographic or video evidence, and can create a prediction of what a suspect's face looks like just using a sample of their DNA. It determines skin, hair and eye colour, as well as face shape and detailed biogeopraphic ancestry. When the police have nothing else to go on this information is invaluable, and can quickly narrow down a list of suspects. It is hoped that as our understanding of DNA improves it will be possible to pick out further characteristics, which will in turn allow even more detailed facial reconstructions to be created.

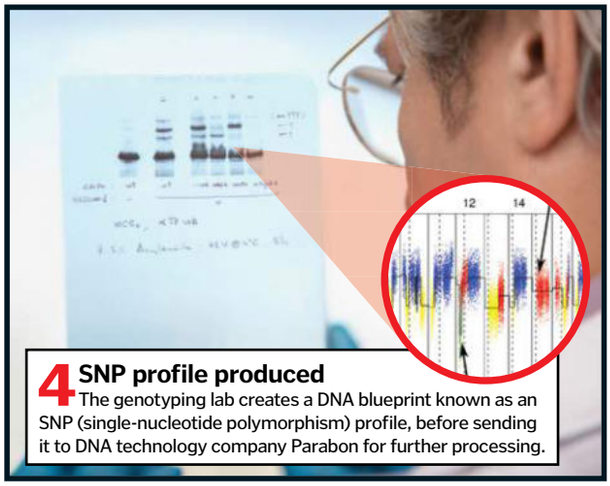


**1 Recovery of evidence**
DNA evidence is initially recovered from the crime scene. This may be from a sample of blood, skin, semen or saliva.

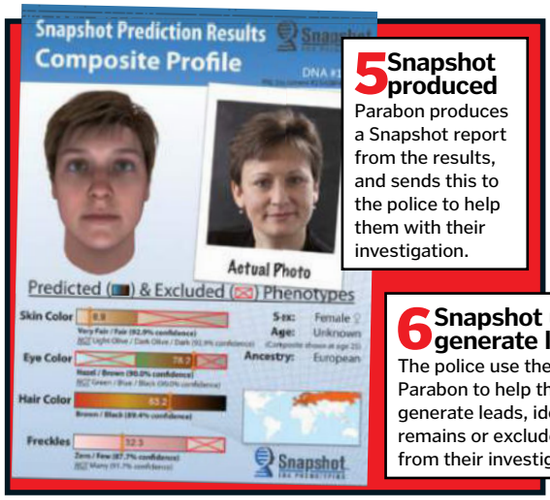


**2 DNA extracted**
Scientists work to carefully extract DNA from the crime scene sample, and then run it through their database to check for a match.

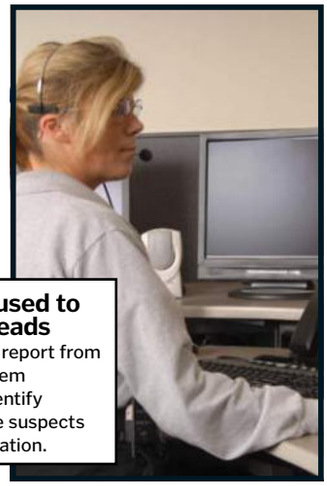
**3 Match found?**
If a match on the database is found, an arrest can be made. If not, the sample is sent to be analysed.




**4 SNP profile produced**
The genotyping lab creates a DNA blueprint known as an SNP (single-nucleotide polymorphism) profile, before sending it to DNA technology company Parabon for further processing.




**5 Snapshot produced**
Parabon produces a Snapshot report from the results, and sends this to the police to help them with their investigation.



**6 Snapshot used to generate leads**
The police use the report from Parabon to help them generate leads, identify remains or exclude suspects from their investigation.



**1985**
The Home Office Large Major Enquiry System (HOLMES) is established, using computer systems to support major investigations.

**1988**
Colin Pitchfork becomes the first person to be convicted of murder on the basis of DNA evidence.

**1995**
The UK sets up a national DNA database, which contains samples from crime scenes, potential suspects and detainees.

**2004**
Police forces in England and Wales have access to tasers, although only specially trained officers are allowed to use them.

**2020?**
It is hoped that advancements in nanotechnology will lead to the development of new forensic techniques, helping to speed up DNA analysis.

# Household plumbing

Find out how a complex system of pipes takes water in and out of your home

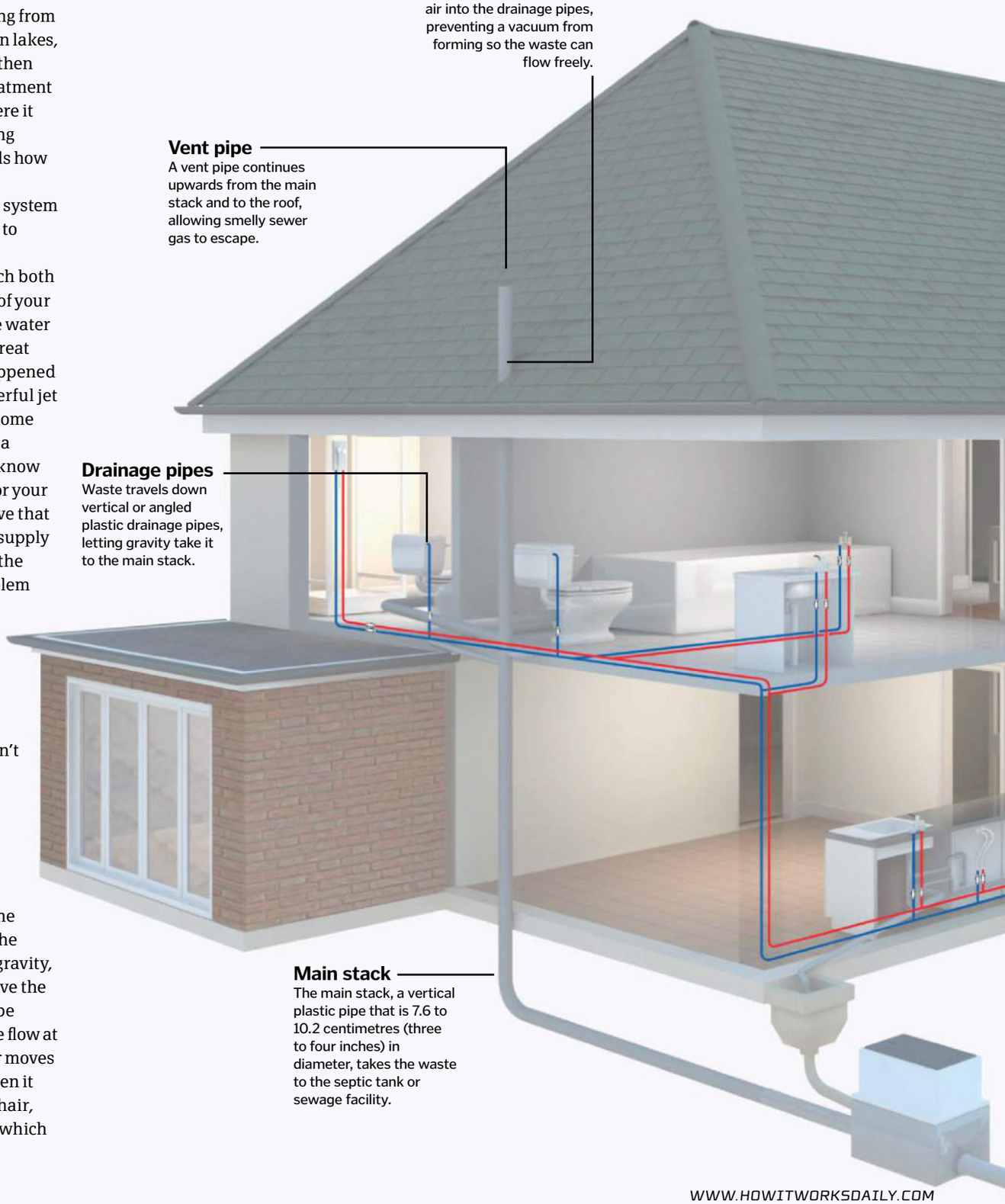
When you turn on the tap, you expect a steady stream of water to come flowing out, but have you ever considered how it got there? Its journey begins as rain falling from the sky, which is collected in lakes, rivers, and the ground and then passed through a water treatment plant for cleaning. From there it travels to your home, passing through a meter that records how much water you use, before reaching a clever plumbing system of supply pipes that takes it to where it is needed.

As it has to be able to reach both the upper and lower floors of your house, pressure pushes the water through these pipes with great force. This means if one happened to burst, the resulting powerful jet of water would flood your home very quickly. To avoid such a disaster, it's a good idea to know where the shut-off valves for your property are. The main valve that shuts off your entire water supply is typically located near to the water meter, but if the problem is confined to a particular area, then most sinks, toilets, baths and showers have their own valves for cutting off their individual water supplies.

The water's journey doesn't stop at your taps though, as the waste water you do not need has to travel back out of your property. This is why every house has a drainage system that is completely separate from the supply system that brings the water in. This system uses gravity, rather than pressure, to move the water, so the pipes have to be angled correctly to keep the flow at the right speed. If the water moves too slowly or too quickly, then it could leave debris, such as hair, dirt or toilet paper behind, which will block the pipes.

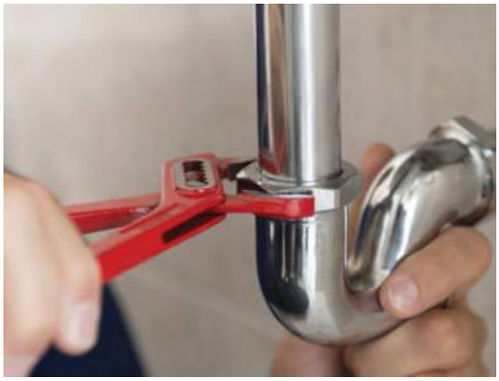
## From pipe to tap to drain

**Water's journey through your home is powered by pressure and gravity**



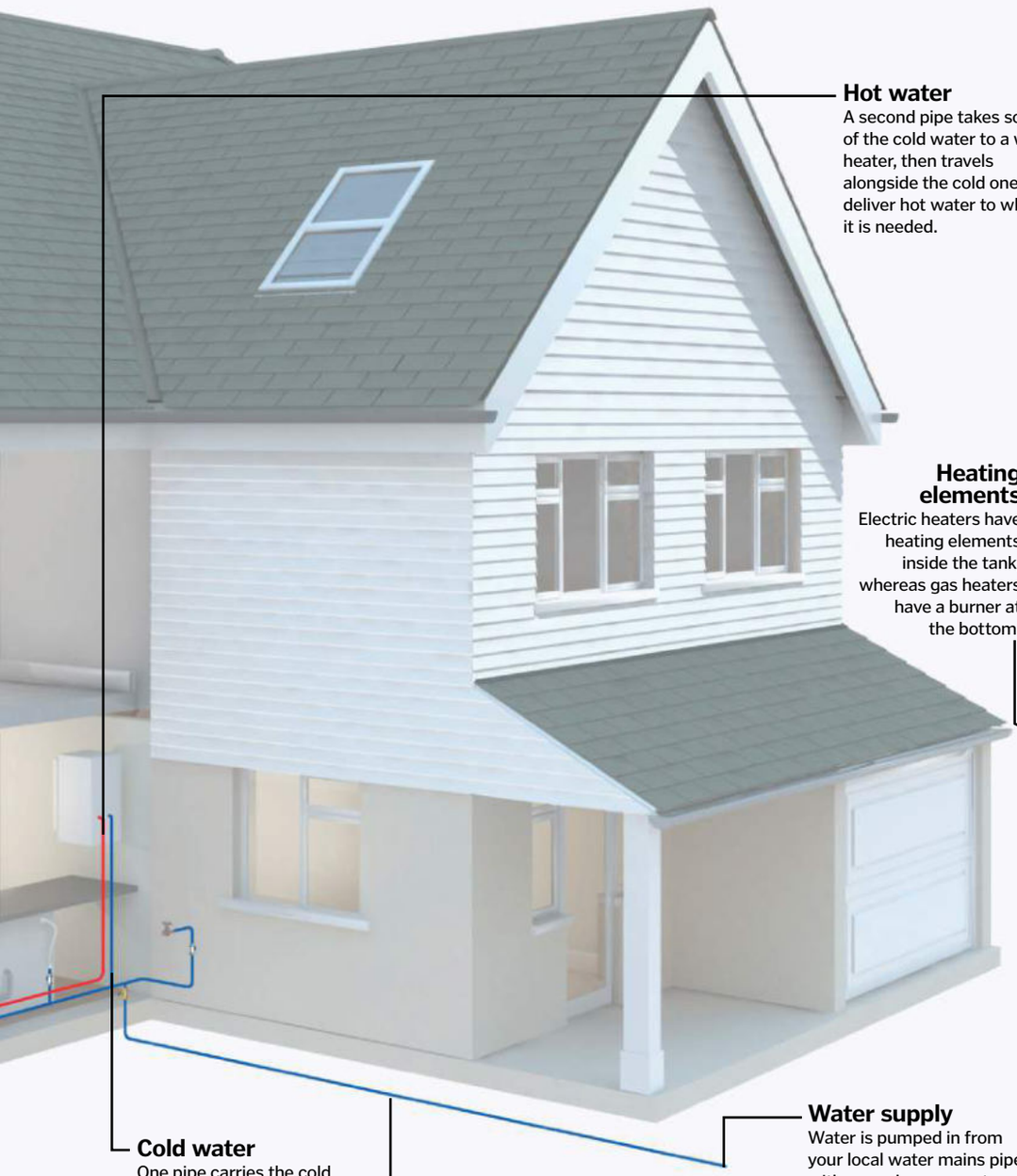
# Smell traps

If look under your kitchen sink, you may notice a U-shaped bend in the pipe beneath the drain. This is called a trap and it is found in the drainage pipes of most household fixtures and appliances. The trap plays the vital role of stopping anything from travelling up the pipe and into your house. When the water drains from your sink, there is enough force to push it around the bend of the trap and through the drainage pipe. However, some of the water will stay behind, filling up the trap to form a seal. This stops any sewer gas from escaping through your drain, not only preventing a nasty smell from filling your home, but also stopping harmful bacteria from being carried into the air. These traps can be removed to allow any blockages to be cleared, but some feature a clean-out plug on the bend that can be removed instead.



# Ventilation system

The typical drainage system used in most houses is DWV, which stands for the drain-waste-vent system. The vent component is essential for allowing the waste to drain away, as without a vent line that lets air enter through the roof, a vacuum would form in the drainage system. This would have a similar effect to placing your finger over the top of a straw before lifting it out of your drink. Until you remove your finger, the vacuum created holds the liquid in the straw, just as a vacuum in a drainage system would hold the water within the pipe.



**Hot water**
A second pipe takes some of the cold water to a water heater, then travels alongside the cold one to deliver hot water to where it is needed.

**Cold water**
One pipe carries the cold water directly to where it is needed, such as the toilet, cold taps and washing machine.

**Supply lines**
Water supply lines are typically made of copper with a diameter of 2.5cm (one inch) or smaller. The wider the pipe, the better your water flow.

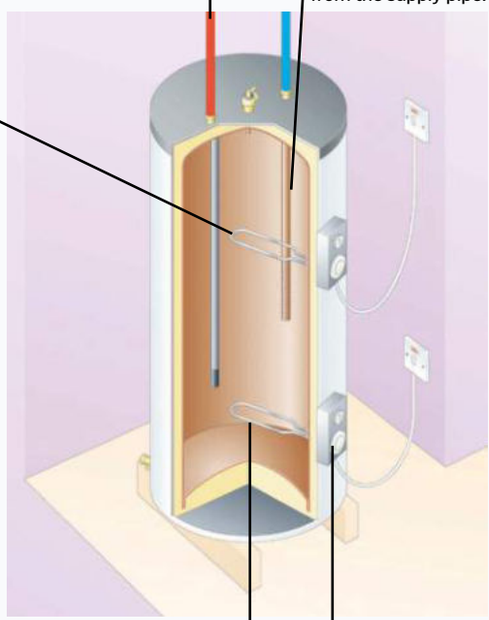
**Water supply**
Water is pumped in from your local water mains pipe with enough pressure to enable it to travel upstairs and around corners.

# Inside a water heater

**Heating elements**
Electric heaters have heating elements inside the tank, whereas gas heaters have a burner at the bottom.

**Hot water pipe**
As the heated water rises above the denser, cold water, it reaches the pipe that carries it away.

**Dip tube**
Cold water is fed directly to the bottom of the tank from the supply pipe.



**Anode rod**
A replaceable magnesium or aluminium rod with a steel core protects the tank from corrosion.

**Thermostat**
This controls the temperature of the water so that it's not too hot or too cold.

# Wireless chargers

## The amazing tech that could spell the end for plugs and cables

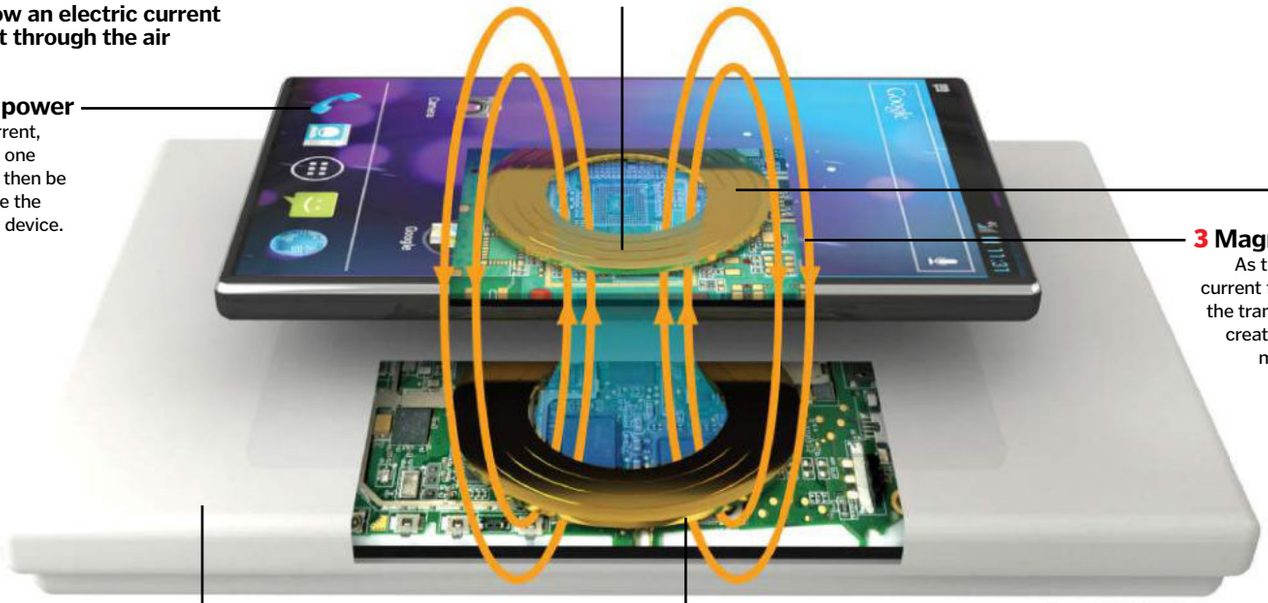
If you have ever had to wrestle with a messy tangle of cables, then the introduction of wireless phone charging will come as a welcome relief – but this useful technology isn't actually all that new. Physicist Nikola Tesla first concluded that you could transfer power between two objects via an electromagnetic field in the late 1800s, and by the 1990s wires and electronics could be made small enough to make wireless charging feasible for devices such as artificial hearts and electric toothbrushes.

These days, the inductive charging method can be used for smartphones, tablets and even electric cars, but if it's so convenient, why aren't we using it all the time? One reason is that it isn't very efficient, as a lot of energy is lost as heat – so your device takes longer to charge. It also requires your device to be very close to the charger to work, so it effectively still tethers it to a power source just like a cable charger.

However, this could change with a new method called inductive wireless charging that is in development and will enable power to be transferred over greater distances.

## How inductive wireless charging works

**Find out how an electric current can be sent through the air**



**5 Direct current**
The alternating current flowing through the receiver coil is then converted into direct current by the receiver circuit.

**4 Receiver**
The magnetic field generates an electric current within the receiver coil of a device when it comes within a close distance.

**6 Battery power**
The direct current, which goes in one direction, can then be used to charge the battery of the device.

**3 Magnetic field**
As the alternating current flows through the transmitter coil it creates a changing magnetic field.

Illustration by Adrian Mann

**1 Power source**
The power coming from the plug sockets in your walls is alternating current, which changes direction several times a second.

**2 Transmitter**
The current is sent to the transmitter circuit in the wireless charger, which then sends it to a transmitter coil of wire.

# How do erasers work?

## Discover why we no longer use bread to rub out our mistakes

To understand how erasers remove pencil marks, we first need to know a bit about the pencil itself. Contrary to popular belief, pencils are no longer made from lead; instead they consist of a mixture of graphite (a soft mineral made up of a crystalline form of carbon) and clay. When you write on a piece of paper, flakes of this mixture cling to the paper fibres, leaving visible marks. Erasers are able to remove these marks simply by being stickier than the paper fibres, so the graphite and clay particles cling to the eraser instead.

In fact, anything stickier than paper can be used as an eraser, and until the 1770s, moist bread was most people's material of choice. Reportedly, when scientist Joseph Priestly accidentally picked up a piece of latex instead of bread, he discovered this new substance could also rub out pencil marks, which is where the name 'rubber' originated from. Nowadays, because natural latex rubber is expensive and some people are allergic to it, erasers are typically made from synthetic petroleum-based rubbers, such as polyvinyl chloride.

Some erasers contain pieces of the volcanic rock pumice to make them more abrasive

# Scalextric App Race Control

## The revolutionary system lets you race like the real thing

Scalextric has had an innovative new update that merges the on-track racing experience with on-screen gameplay functionality. By attaching the new ARC App Race Control powerbase you can wirelessly connect your smart device to the track and use the ARC app to really personalise your races.

There are several different race modes to choose from, including a quick drag race along the straight, and a full Grand Prix that requires pit stop planning and qualifying for pole position.

Alternatively, you can get started straight away with pre-set race types, organise a tournament with several heats, or set your desired number of practice laps to refine your skills. You can also set the drivers' names to easily track the performance of you and your opponents, and save your various track designs by uploading photographs to the app. One of the most exciting features of the ARC race app system is that it is compatible with all Scalextric sets, whether new or old. If you already have a set at home, then you can simply replace the old powerbase with the new Bluetooth-enabled one to unlock the app's new features, or you can start from scratch with the brand new ARC ONE set.



The ARC ONE app lets you customise race settings and record each driver's performance

### ARC ONE App Race Control key features

**Jump Start**
Set a jump start penalty should a driver jump the lights.

**Start Reaction Times**
Records each driver's reaction time when the lights go out to pulling the throttle.

**Top Speed**
Records the fastest speed across the start line.

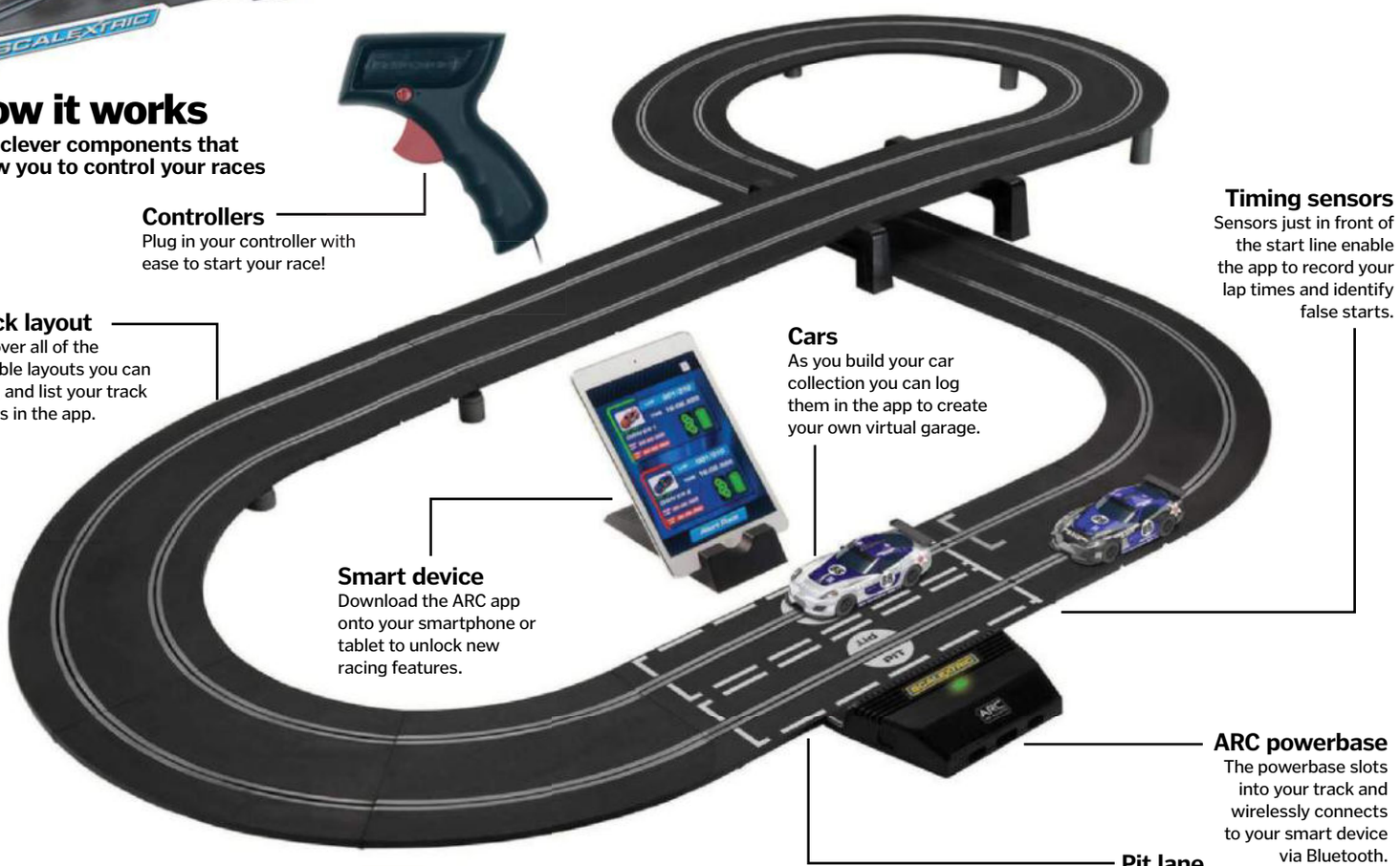
**Lap Counting & Timing**
See your current and remaining lap times.

**Fuel Load**
When car runs out of fuel pit stops will be required - miss the pits and risk disqualification.

**Tyre Wear**
Add another dimension to your race by monitoring your tyre wear and choosing the right time to pit.

## How it works

**The clever components that allow you to control your races**




**Controllers**
Plug in your controller with ease to start your race!

**Track layout**
Discover all of the possible layouts you can build, and list your track pieces in the app.

**Smart device**
Download the ARC app onto your smartphone or tablet to unlock new racing features.

**Cars**
As you build your car collection you can log them in the app to create your own virtual garage.

**Timing sensors**
Sensors just in front of the start line enable the app to record your lap times and identify false starts.

**ARC powerbase**
The powerbase slots into your track and wirelessly connects to your smart device via Bluetooth.

**Pit lane**
Take a pit stop to recharge your car when the app indicates that your fuel is running low.

SCALEXTRIC **www.scalextric.com**

# GoPro HERO4 Session teardown

## Take a look inside the smallest and lightest action cam yet

GoPro has quickly become synonymous with action cameras, enabling extreme sports fans to capture their best stunts from dynamic new perspectives. The latest model in the line-up, the GoPro HERO4 Session, makes this even easier thanks to its tiny yet rugged frame. Weighing just 74 grams (2.6 ounces), the Session is 50 per cent smaller and 40 per cent lighter than other GoPro HERO4 cameras because it doesn't need a separate protective housing to make it waterproof.

The camera is completely watertight, enabling it to be used underwater at depths of up to ten metres (33 feet). Plus, without a bulky case to get in the way, the dual microphones are able to pick up higher-quality audio and the camera can automatically switch between the front and back microphones to capture the best sound with reduced wind noise.

The cube-shaped camera is compatible with most existing GoPro mounts, so it can be attached to a helmet, bike, surfboard and more. It also comes with a new ball joint buckle mount, that lets you instantly tilt and rotate the camera by 360 degrees, while auto image rotation ensures your footage is the right way up.

With only one button, the Session is very easy to control, yet still features a wide range of shooting options, from top quality 1440p-resolution video to slow-motion capture at 100 frames per second. You can also shoot still images too, with time-lapse mode for capturing slow-changing scenes and burst mode for fast-paced action.

## Inside the Session

**How does this waterproof camera work beneath the waves?**

**O-ring**
This waterproof seal protects the lens and other internal components beneath the removable lens cover.

**Communication chip**
Bluetooth and Wi-Fi connectivity enable the camera to be controlled via a GoPro remote or a free app on your smartphone.


**Battery**
The fixed rechargeable lithium-ion battery lets you record high quality video for up to two hours on a full charge.


The Session automatically adjusts its capture orientation if you accidentally mount it upside down, so your footage is always the right way up.

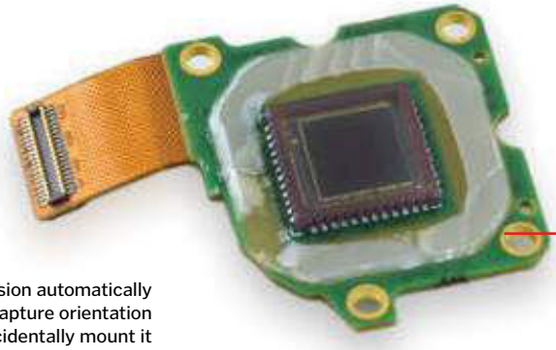
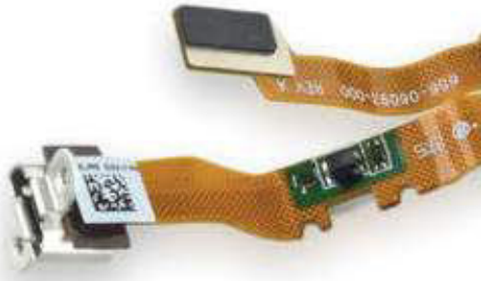


**Image sensor**
The eight-megapixel sensor captures high-resolution still images and video up to 1440p at 30 frames per second.



*"The Session is very easy to control, yet features a wide range of shooting options"*

**Waterproof casing**
An outer rubber cover is glued to an inner plastic casing to provide watertight protection for the internal components.

**Lens cover**
If it gets damaged, the glass lens cover can be unscrewed for replacement or repairs.

**External controls**
A single button powers the camera on and off and starts and stops recording, plus a small backlit display indicates the recording mode.

**Motherboard**
This chip houses the image and video processor, in-camera memory and power management unit.

**Lens**
The all-glass lens provides an ultra-wide angle field of view but with reduced distortion to combat the fish-eye effect.

**Connection ports**
Sealed behind a hinged door, the microSD slot allows footage to be stored, and the micro-USB port is for charging and file transfer.

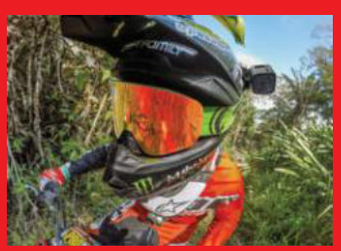
## Top Stats

| | |
|---|---|
| **Weight:** | 74g (2.6oz) |
| **Megapixels:** | 8MP |
| **Price:** | £329.99 / $399.99 |
| **Dimensions:** | 35 x 35 x 35mm (1.4in) |
| **Waterproof:** | Up to 10m (33ft) |
| **Field of view:** | 170 degrees |

## Capture the action

**Ride the waves**
The surf edition of the Session comes with a surfboard mount and camera tether, so you can safely use it on the ocean waves. There's also an optional Floaty accessory that will stop the camera from sinking if it does come loose.

**Personal perspective**
The camera's small, cube-shaped design and supplied low-profile frame mount means you can wear it as close to your eye-level as possible. This helps you capture your own unique view of the action to keep and share.



**Get creative**
As well as being able to record high quality video at regular speed or in slow motion, you can also capture a burst of still images at ten frames per second, or create a time lapse video by shooting at intervals ranging from 0.5 to 60 seconds.

# ROAD CAR TO RACECAR

## How normal, road-going cars are transformed into racetrack titans

In our contemporary world, the motor vehicle makes for a common sight on the public road. This is for good reason: there are currently more than one billion cars on Earth, helping us execute both short and long distance journeys in a variety of styles, be it in the name of luxury, practicality or simply pleasure.

However, aside from its ability to provide a form of travel to the masses, there is another facet to the role of the motor vehicle in society. Part of a culture that has existed ever since the birth of the car itself; as long as cars have been made, they've been raced, in various sporting disciplines. One of the earliest events was the Paris-Rouen contest in 1894, where cars travelled the 126 kilometres (78 miles) between the two French cities. As motoring developed, so did motorsport, giving rise to other championships such as Formula One in 1950, and touring cars in 1987.

As motorsport has evolved, so too have the cars that compete in its various forms, and many manufacturer-backed vehicles now take to the start line under a wholly different appearance from what we might see on the road. This is because a mass-produced vehicle in road-going form is designed for general use around the world. The majority of features, such as a comfortable ride or air conditioning, are not needed for motorsport, and so begins a monumental upheaval of the humble production car – usually right back to its bare shell – all in the name of triumphing once that chequered flag falls.

The result is a vehicle that's far removed from the 'jack of all trades' production car. The sums of money involved in the transformation are huge, and sponsorship deals are incredibly important for providing the requisite funding. Motorsport is a lucrative business, though, which is why nearly all major motoring manufacturers compete in at least one event. After all, it's the best shop window for your product, with most companies adopting a 'win on Sunday, sell on Monday' mentality, referring to the potential increase in car sales thanks to a race win the previous weekend. The changes, then, are very much worth it.


**After**

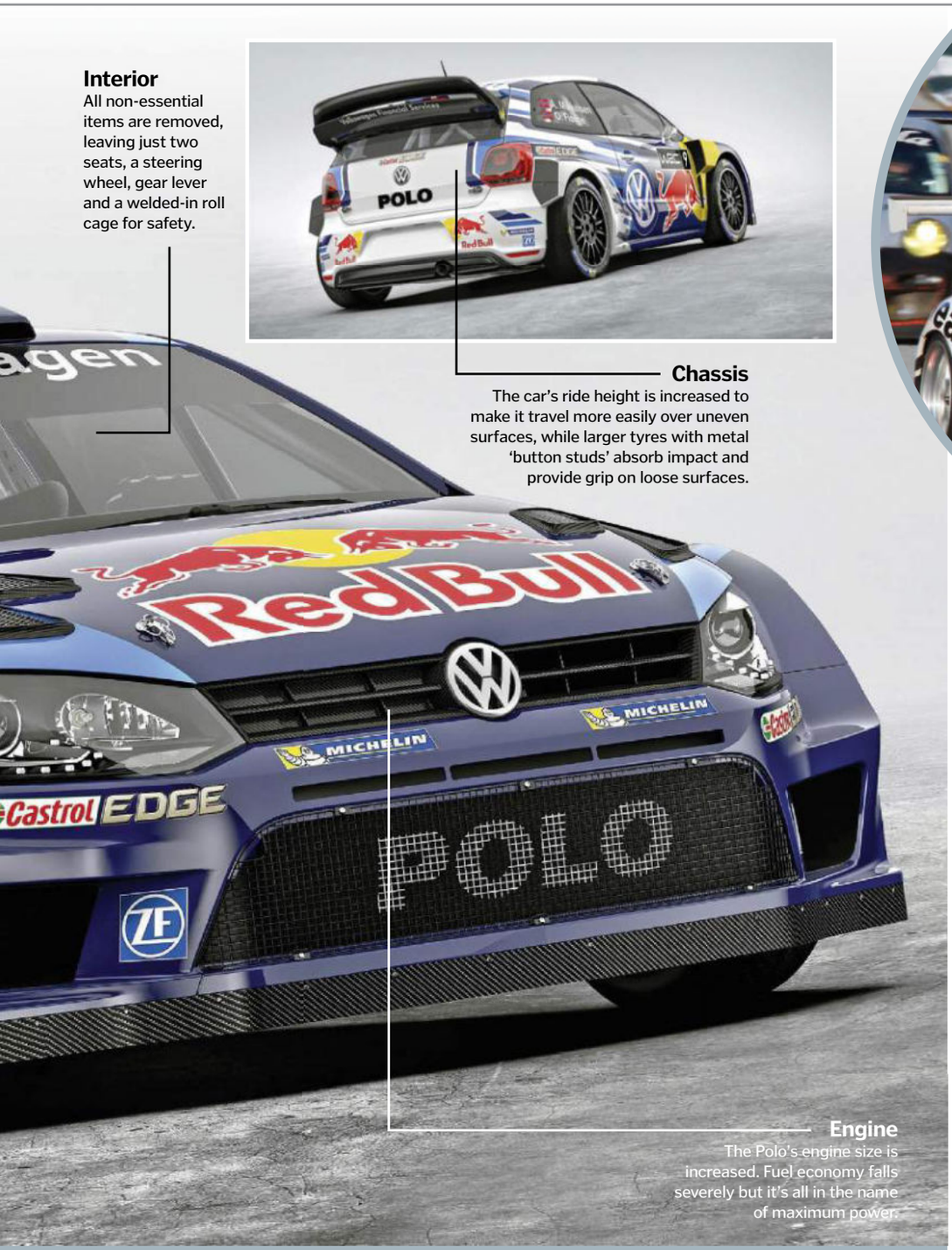
**Body**
Steel and alloy panels are replaced with fibreglass to reduce weight. The windscreen remains as glass but all other windows are plastic.

## Rallying

### In a sport as wild as the terrain it graces, a rally car must be specially prepared for its many challenges

Rallying is a race against time. Only one car takes on a rally stage at any one time, with recorded timings forming a league table as drivers jostle for positions on the leaderboard. Rally stages are usually held off-road and on rough terrain, and so a competitive car must be able to travel over the uneven landscape, and quickly. To ensure this is possible, manufacturers select a road car that is small and nimble, with a lightweight and short wheelbase, helping it to change direction quickly and fit through even the tightest paths in forests. Volkswagen, for example, utilise their Polo, a three-door hatchback model.

To transform it into a competition-ready machine, Volkswagen removes any unnecessary equipment: the rear seats, carpets, stereo and speakers are all scrapped to reduce weight. Then the car is strengthened to help withstand any shunts and bumps: a full roll cage is welded into the car, while a higher, long-travel suspension is fitted to ensure the car has plenty of ground clearance and can absorb any prominent bumps in the uneven surface. The engine is tuned for added performance and, unlike most motorsports, two seats are needed in the front rather than one, to accommodate the co-driver.




**Interior**
All non-essential items are removed, leaving just two seats, a steering wheel, gear lever and a welded-in roll cage for safety.

**Chassis**
The car's ride height is increased to make it travel more easily over uneven surfaces, while larger tyres with metal 'button studs' absorb impact and provide grip on loose surfaces.

**Engine**
The Polo's engine size is increased. Fuel economy falls severely but it's all in the name of maximum power.


# Drifting

## A sport dedicated to sliding means substantial revisions for this tyre-shredding spectacular

Smoking, screeching tyres and a wayward rear end may portray a picture of a car that's out of control, but drifting is a dark art that arguably represents the zenith in high-speed car control from a driver. Although boasting a huge following in America, drifting is a relatively new phenomenon in the UK. This discipline is all about grip, where big slides are worth big points around a track or specially mapped course.

In preparation for a life going sideways, drift cars are lowered to the floor to reduce body roll, and stiffened with anti-roll bars – perfect for flicking that rear end out quickly. A strengthened hydraulic handbrake with a bigger, easily accessible lever is installed, as a driver will use this regularly to lock the rear wheels to help start a slide. The car's steering is also revised to ensure the front wheels can have up to 60 degrees of lock, giving the driver added manoeuverability. A 700bhp engine is fitted along with an all-important limited slip differential to ensure big slides, while long-lasting tyres are essential to ensure the car can remain competitive for as long as possible, even through all that burning of rubber!

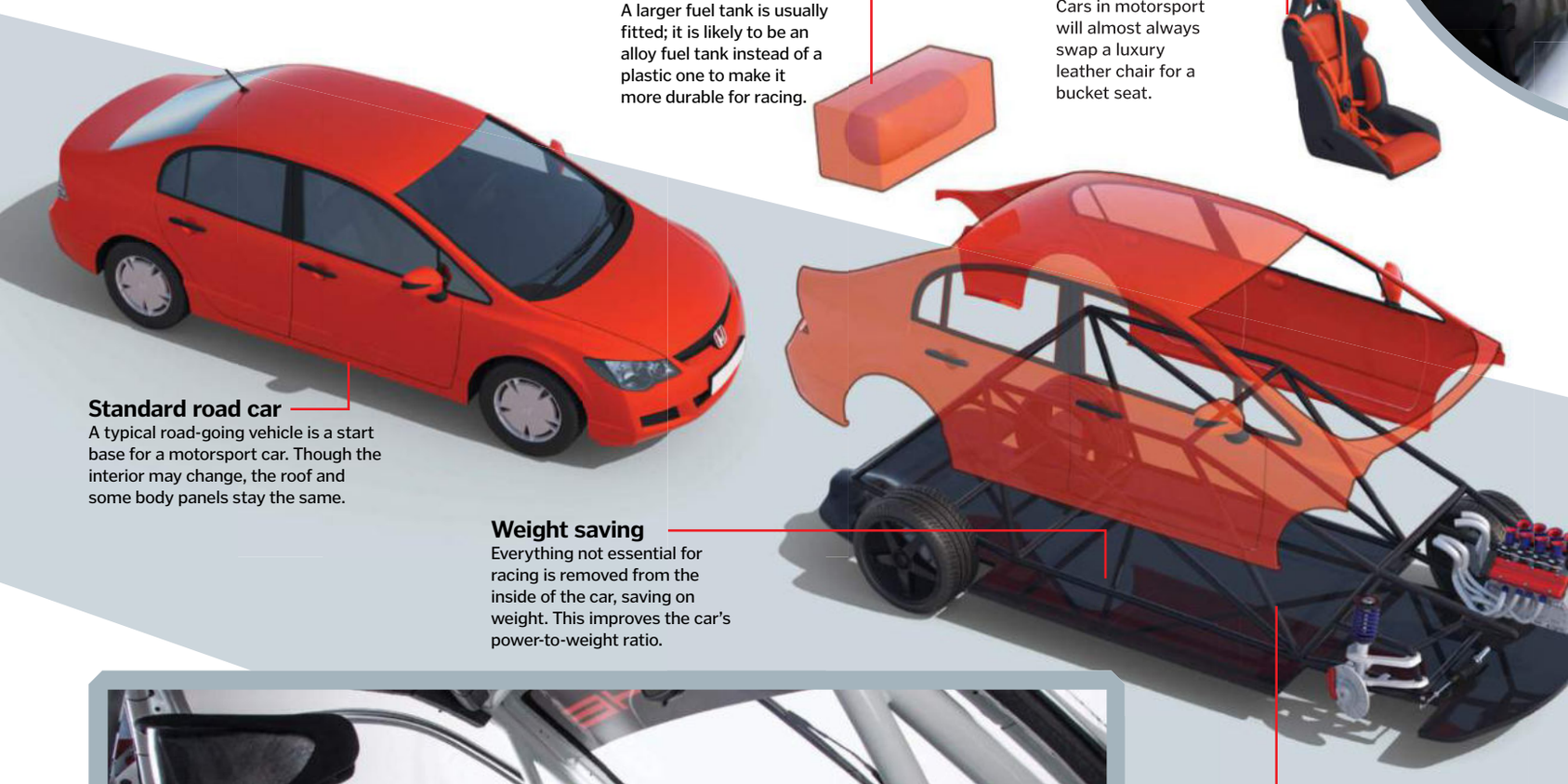


A drift car exerts huge power for big speeds, while a refined chassis ensures precision power slides

# Modifications

## A behind-the-scenes look at the transformation process

Unlike the build of a mass-produced car – which takes place on a production line and is usually carried out by robots – the transformation to a race car is usually done by hand in small, highly-trained teams. The work isn't over once the build is complete, either. Tinkering is often done to adjust the car after practices, to ensure even the smallest of gains over rivals, and it's common for a race car's engine to be taken out, stripped down and completely rebuilt after each race weekend, too. This is because an engine's components are placed under extreme strain for long periods of time during a race, and letting them deteriorate could affect performance later in the season.



**Fuel tank**
A larger fuel tank is usually fitted; it is likely to be an alloy fuel tank instead of a plastic one to make it more durable for racing.

**Driver's seat**
Cars in motorsport will almost always swap a luxury leather chair for a bucket seat.

**Standard road car**
A typical road-going vehicle is a start base for a motorsport car. Though the interior may change, the roof and some body panels stay the same.

**Weight saving**
Everything not essential for racing is removed from the inside of the car, saving on weight. This improves the car's power-to-weight ratio.

**Roll cage**
With the interior stripped, a roll cage is welded or bolted in, protecting the driver should the car roll onto its roof.

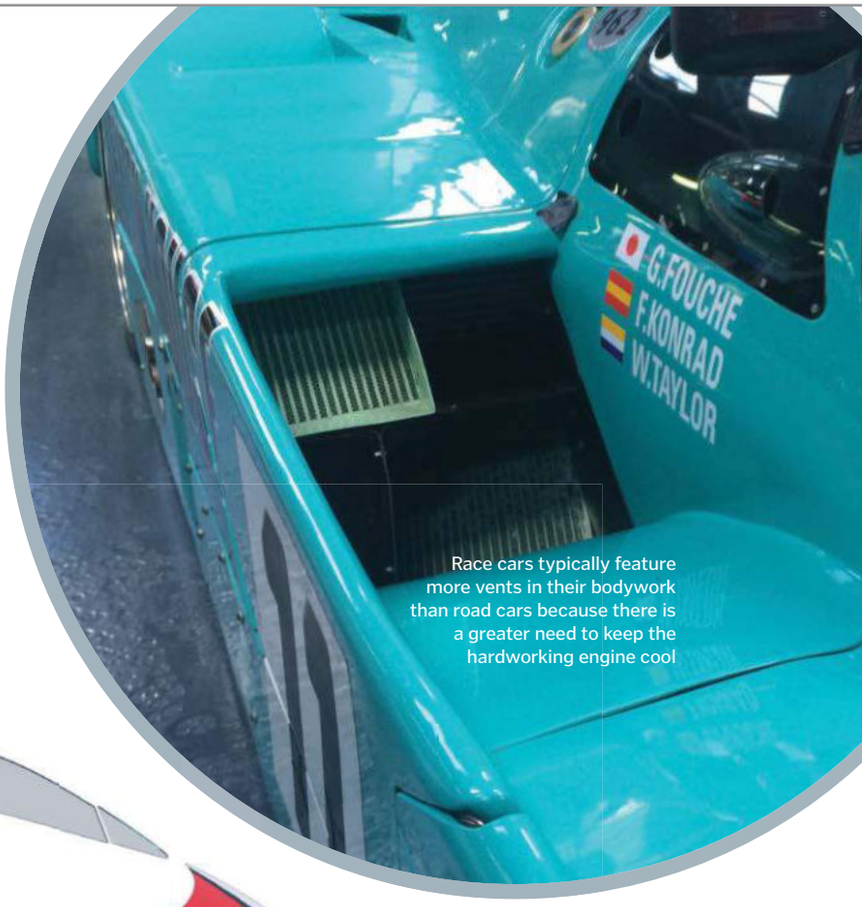
A roll cage adds stiffness to a car and provides protection in a crash

## Roll cage: A vital safety device

Commonly found inside competitive cars, a roll cage is usually a mandatory safety component. It is designed to protect the occupants inside of a vehicle in the event of it rolling over, stopping the car from flattening. A roll cage looks like a large metal frame inside the passenger compartment of a car, stretching from floor to ceiling and, usually, from front to back. This large frame effectively shields the driver, so that in the event of an accident, the car doesn't crumple in on them with nasty – and potentially fatal – consequences. In top-level motor racing, the roll cage is substantial, with cross braces behind doors protecting the driver in the event of a side-on shunt. A roll cage can be bolted in, but welding it in place increases the structural rigidity of the car – which also helps improve the car's agility when cornering, providing another key motorsporting edge.

**Bucket chair**
This keeps the driver rooted to the spot even under high G-forces and protects them in the event of an accident.

**Safety belt**
A lap belt is replaced by a six-point harness, holding the driver firmly in place.

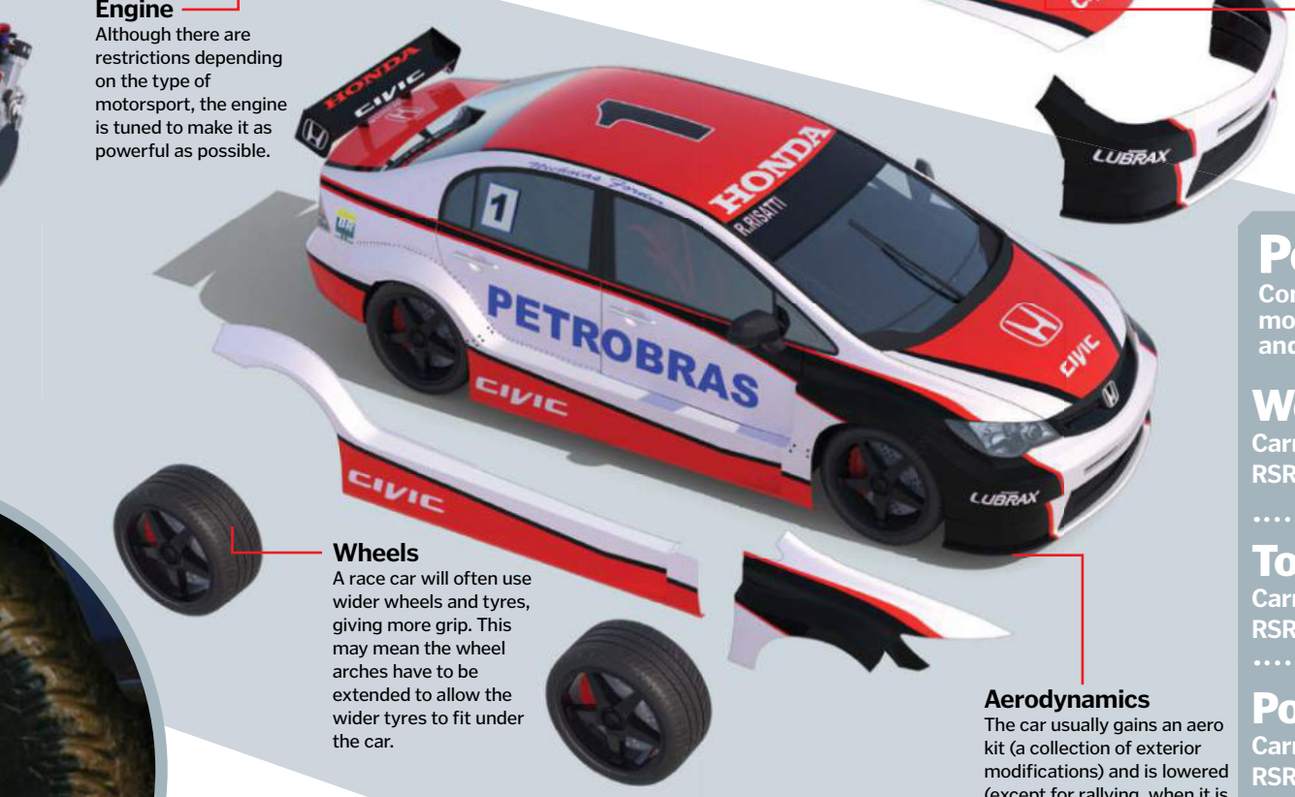



Race cars typically feature more vents in their bodywork than road cars because there is a greater need to keep the hardworking engine cool

**Lightweight panels**
The bonnet and doors are usually replaced with lightweight carbon fibre ones, reducing weight.

**Engine**
Although there are restrictions depending on the type of motorsport, the engine is tuned to make it as powerful as possible.

**Livery**
Sponsorship decals are added to the car, which is a core source of income for race teams.




**Wheels**
A race car will often use wider wheels and tyres, giving more grip. This may mean the wheel arches have to be extended to allow the wider tyres to fit under the car.

**Aerodynamics**
The car usually gains an aero kit (a collection of exterior modifications) and is lowered (except for rallying, when it is raised), aiding downforce and improving handling.



Rally tyres often feature a deep tread, to provide extra grip even on loose terrain, digging into the floor and increasing traction for the car. Some tyres are embedded with steel studs, offering improved grip in snow and icy conditions for winter rallies.

## Porsche 911

**Comparing the specs for motorway (911 Carrera) and motorsport (911 RSR)**

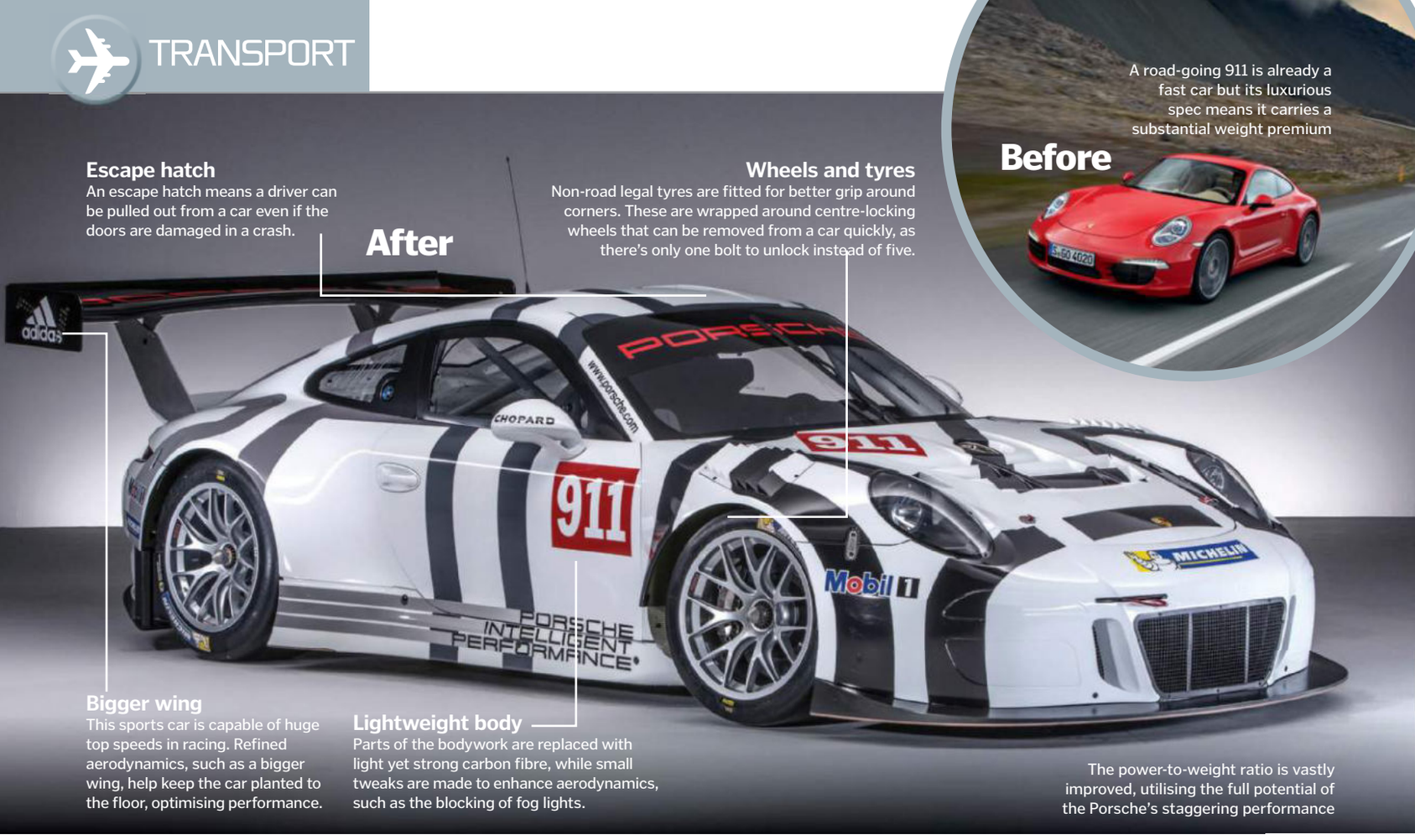
### Weight
Carrera: 1,430kg (3,153lb)
RSR: 1,245kg (2,745lb)

### Top speed
Carrera: 295km/h (183mph)
RSR: 306km/h (190mph)

### Power
Carrera: 370bhp
RSR: 470bhp

### Brake disc size
Carrera: 330mm (13in)
RSR: 380mm (15in)

Illustrations by Nicholas Forder




# Endurance racing

## Championing at the ultimate motorsport means going fastest for the longest

While sprint racing has long proved a popular motor-racing discipline, endurance racing is viewed as the ultimate in motorsport circles. With races around a circuit often lasting for up to 24 hours at a time, endurance racing is all about going fast and lasting the distance. To do this, teams take a road car already assured of its performance pedigree (Ferrari currently use their 458 supercar, while Porsche use their ubiquitous 911) and make refinements to guarantee excellence in longevity. The car is then put through its paces in the mammoth race, with the distance shared by a team of drivers.

Vast aerodynamic improvements ensure the car can excel at speeds high above the normal limit for a road, while quick-release wheels and easy-to-replace bumpers are used to cut down on pit stop times. Slick racing tyres are used to provide stellar grip (these are not legal on the road as their zero tread depth makes them a hazard in wet conditions) and bigger brakes are fitted that can tolerate prolonged use in extreme temperatures. Although a bigger fuel tank may appear useful for a long distance race, this is often not needed as carrying lots of fuel can incur a needless weight penalty.

**DASHBOARD**

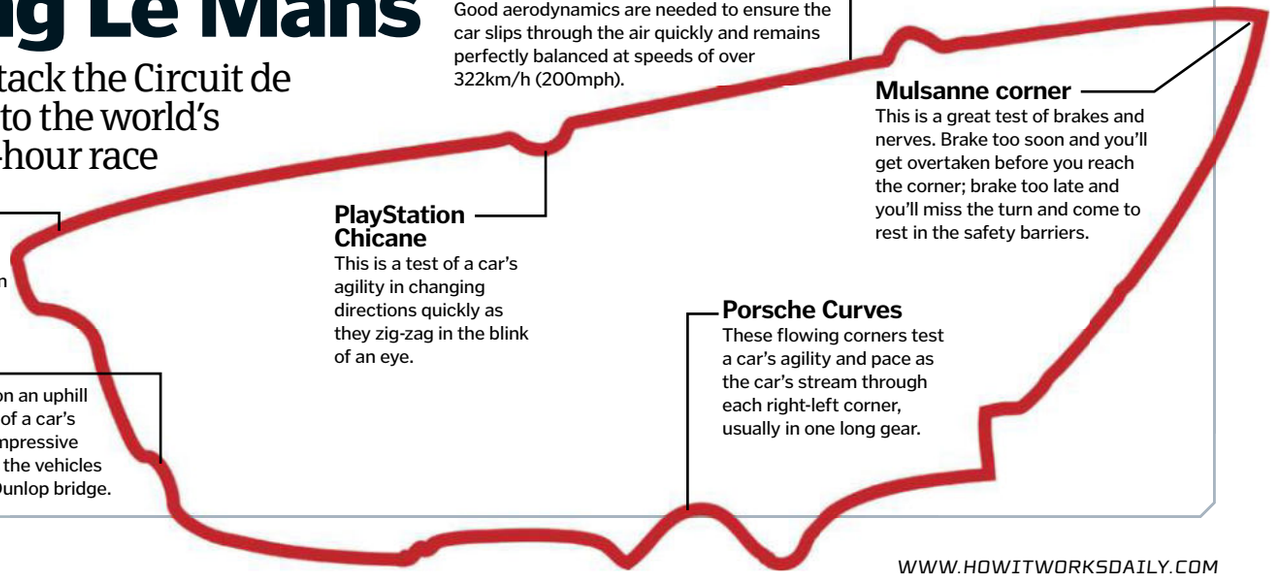
**AIR LINE**

**BUCKET SEAT**

**ROLL CAGE**

# Tackling Le Mans

## Here's how to attack the Circuit de la Sarthe, home to the world's most famous 24-hour race



**Mulsanne Straight**
Good aerodynamics are needed to ensure the car slips through the air quickly and remains perfectly balanced at speeds of over 322km/h (200mph).

**Mulsanne corner**
This is a great test of brakes and nerves. Brake too soon and you'll get overtaken before you reach the corner; brake too late and you'll miss the turn and come to rest in the safety barriers.

**Tertre Rouge**
It's all about the exit of this corner, as cars will want to put as much power as possible down early to take advantage of the long Mulsanne Straight.

**PlayStation Chicane**
This is a test of a car's agility in changing directions quickly as they zig-zag in the blink of an eye.

**Porsche Curves**
These flowing corners test a car's agility and pace as the car's stream through each right-left corner, usually in one long gear.

**Dunlop Curve**
These series of corners on an uphill gradient are a great test of a car's chassis and provide an impressive display for spectators as the vehicles pass under the famous Dunlop bridge.

# Stock car racing

## This grassroots discipline involves plenty of contact

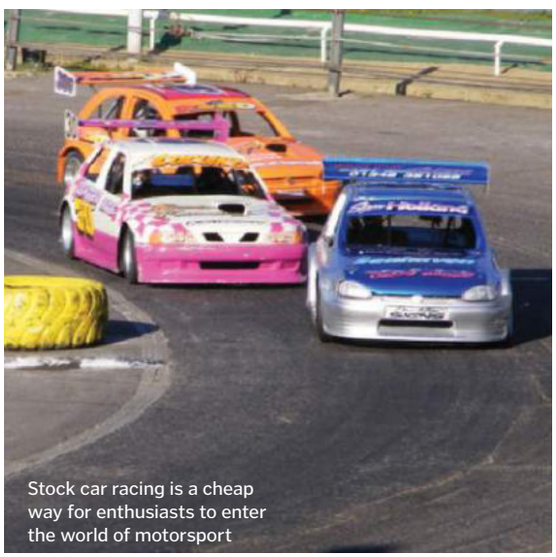
A low-budget hatchback is saved from the scrap heap and prepared for some rough racing

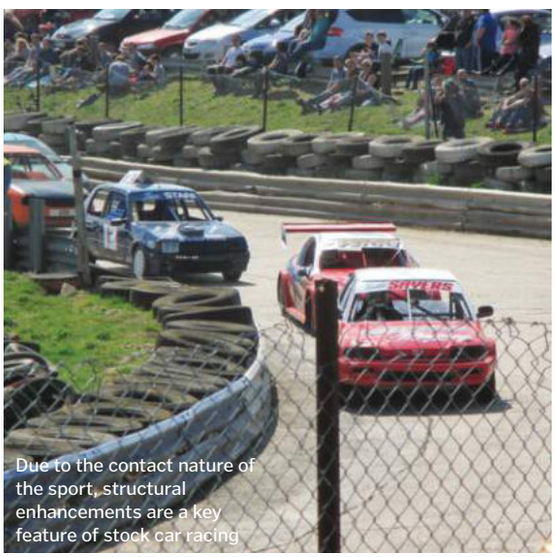
Stock car racing is a cheap, entry-level form of motorsport, worlds away from the lavishness of endurance racing. The idea is to complete as many laps as possible around an oval circuit. However, where contact in other motor sports is frowned upon, here it is perfectly acceptable. This means that the majority of cars competing are low value vehicles saved from the scrap heap.

Due to the contact nature of the sport, stock cars remove all glass windows and lights to stop them shattering on impact. A roll cage is vital here in protecting the driver too, while external bull bars are usually found mounted over the front grill, protecting the engine in the event of an impact to the front of the car, and allowing the vehicle to continue in the race. Cars usually drive clockwise around a circuit, so a left-hand-drive car is desirable as the driver will be placed on the outside of a corner, helping with natural weight transfer.

A racing steering wheel is fitted (without an airbag of course, as it would go off too easily), while removing the airbox de-restricts airflow into the engine, freeing up more power for the driver. Stock cars are devoid of any fancy liveries or artwork to the body, as it'll only get scraped off or crumpled.

The car is stripped to its bare shell, with reinforcements added to withstand impacts from other cars


Stock car racing is a cheap way for enthusiasts to enter the world of motorsport


Due to the contact nature of the sport, structural enhancements are a key feature of stock car racing

## What makes F1 different?

Even to the novice, it's immediately evident that the spectacle of a Formula One car with its open cockpit, huge wing and exposed wheels reveals a vehicle that bears no resemblance whatsoever to any form of road-going contemporary. Whereas most other motorsports mould the competencies of a production car for competition, with Formula One, it's the other way around: new technologies garnered here are then passed on to future production cars. A great example of this is paddle shift gear change, which enables lightning quick gear changes without the driver having to remove their hand from the steering wheel. First pioneered by F1 cars, the technology is now commonplace on every Ferrari leaving the Maranello factory. A more recent evolution is a kinetic energy recovery system, or KERS, which harvests energy from braking and stores this for later use under acceleration. This technology is currently utilised on the McLaren P1 hypercar.


F1 cars are purposely designed from the ground up, unlike the cars used in sports such as rallying or endurance racing

# How aircraft toilets work

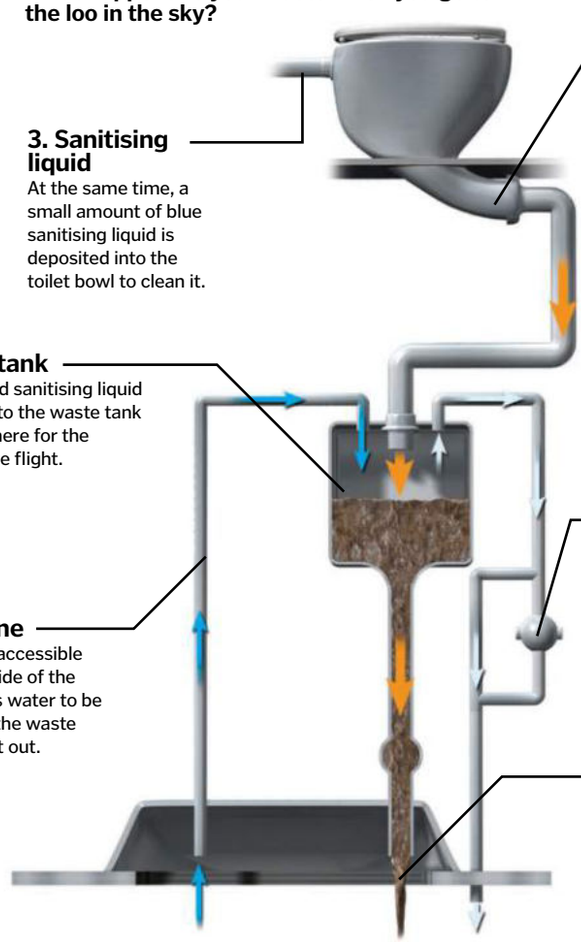
## The powerful vacuum system that flushes your waste at 30,000 feet

The incredibly loud and powerful suction of aircraft toilets might make you jump when you flush, but it is there for a good reason. The conventional toilet you use at home wouldn't be practical on a moving jet as the toilet bowl full of water would be likely to spill during turbulence. As this water, with the help of gravity, is required to flush out the waste, another system had to be developed to empty the bowl effectively.

Until 1982, electric pumps were used to send a blue sanitising liquid into the toilet bowl with every flush and push out the waste. However, this required hundreds of gallons of the stuff to be carried on every flight, taking up lots of weight and space. Nowadays, most aircraft use vacuum toilets, which only use very small quantities of sanitising liquid for the purpose of cleaning the bowl. The waste is removed using powerful suction created by a vacuum in the pipes, but don't worry, unless you are able to perfectly seal the bowl with your backside, you won't get stuck to the seat!

## Vacuum toilet tech

**What happens to your waste when you go to the loo in the sky?**



**2. Flush**
When the toilet is flushed, a valve underneath opens and the vacuum in the pipes sucks the waste out.

**3. Sanitising liquid**
At the same time, a small amount of blue sanitising liquid is deposited into the toilet bowl to clean it.

**4. Waste tank**
The waste and sanitising liquid are sucked into the waste tank and remain there for the duration of the flight.

**1. Vacuum generator**
A pump draws the air out of the pipes and the waste tank to create a vacuum.

**6. Rinse line**
Another pipe accessible from the outside of the aircraft allows water to be pumped into the waste tank to rinse it out.

**5. Drain valve**
When on the ground, a drain valve on the outside of the aircraft is opened and the waste is vacuumed out of the tank.

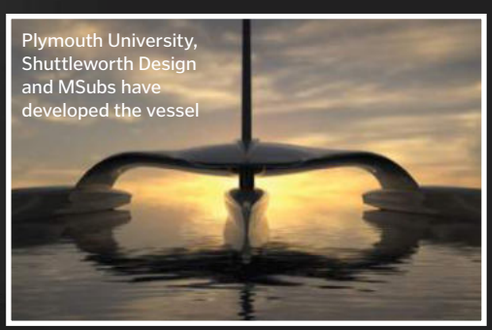
# Unmanned ships

## The world's first full-sized autonomous ship will only have drones for company

Named after the famous ship that once took pilgrims from England to America, the Mayflower Autonomous Research Ship (MARS) will have a much lonelier journey. Powered by renewable wind, ocean current and solar energy, it will replicate this historic journey with no crew, using only GPS and onboard collision avoidance systems to navigate.

Two sails will enable it to move at 37 kilometres (23 miles) per hour, but on calmer days these will be stowed away so that more light can reach the solar panels. These will then power an electric motor with a top speed of 23 kilometres (14 miles) per hour.

The ship will gather meteorological, oceanographic and climate data using a team of onboard drones, and is due to set sail from Plymouth, UK in 2020, the 400th anniversary of its namesake's voyage. It will take seven to ten days to cross the Atlantic.



Plymouth University, Shuttleworth Design and MSubs have developed the vessel

# Panama Canal

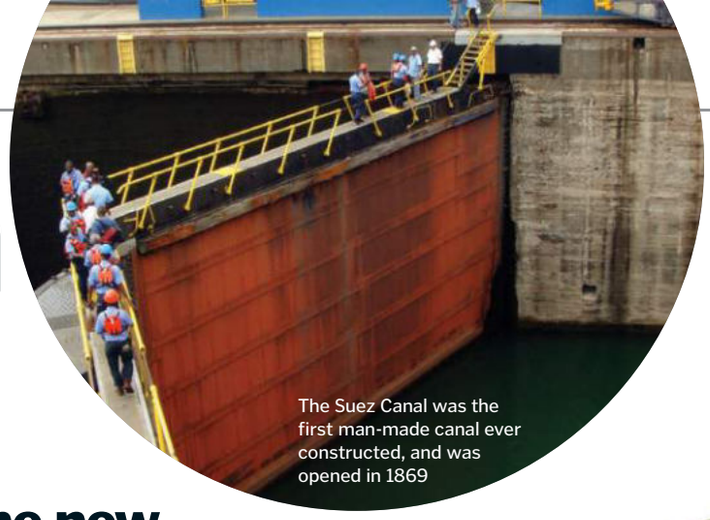
## How this engineering marvel is getting an upgrade a century later

When the Panama Canal first opened in August 1914, many considered it to be the greatest engineering feat ever accomplished. It allowed ships travelling between New York and San Francisco to cut their journey by a colossal 12,669 kilometres (7,872 miles), as they no longer had to go around the southernmost point of South America. Roughly 27 million kilograms (60 million pounds) of dynamite were used to excavate and construct the canal, along with 3.8 million cubic metres (135 million cubic feet) of concrete.

Traffic in the world's oceans has quadrupled over the past 20 years; mammoth cargo ships now transport 95 per cent of imported goods to American shores. Due to this, it was decided that the canal needed some serious renovation and expansion to keep pace with the modern shipping industry. More than 100 studies were conducted to find out what would be the most appropriate plan of action, taking into account the environmental impact of the changes and the technical engineering that would be required.

A £3.5 billion ($5.25 billion) project has been devised, which will involve four major components: a Pacific access channel, an additional set of locks, improvements to the water supply and enhanced navigation channels. Once complete, the canal will be able to support a third lane of traffic, and will be roomy enough to allow ships almost three times the current maximum size permitted, carrying 2.5 times the number of containers. Passage through the new locks will not be cheap for the largest vessels, which currently pay hundreds of thousands of dollars to pass through.

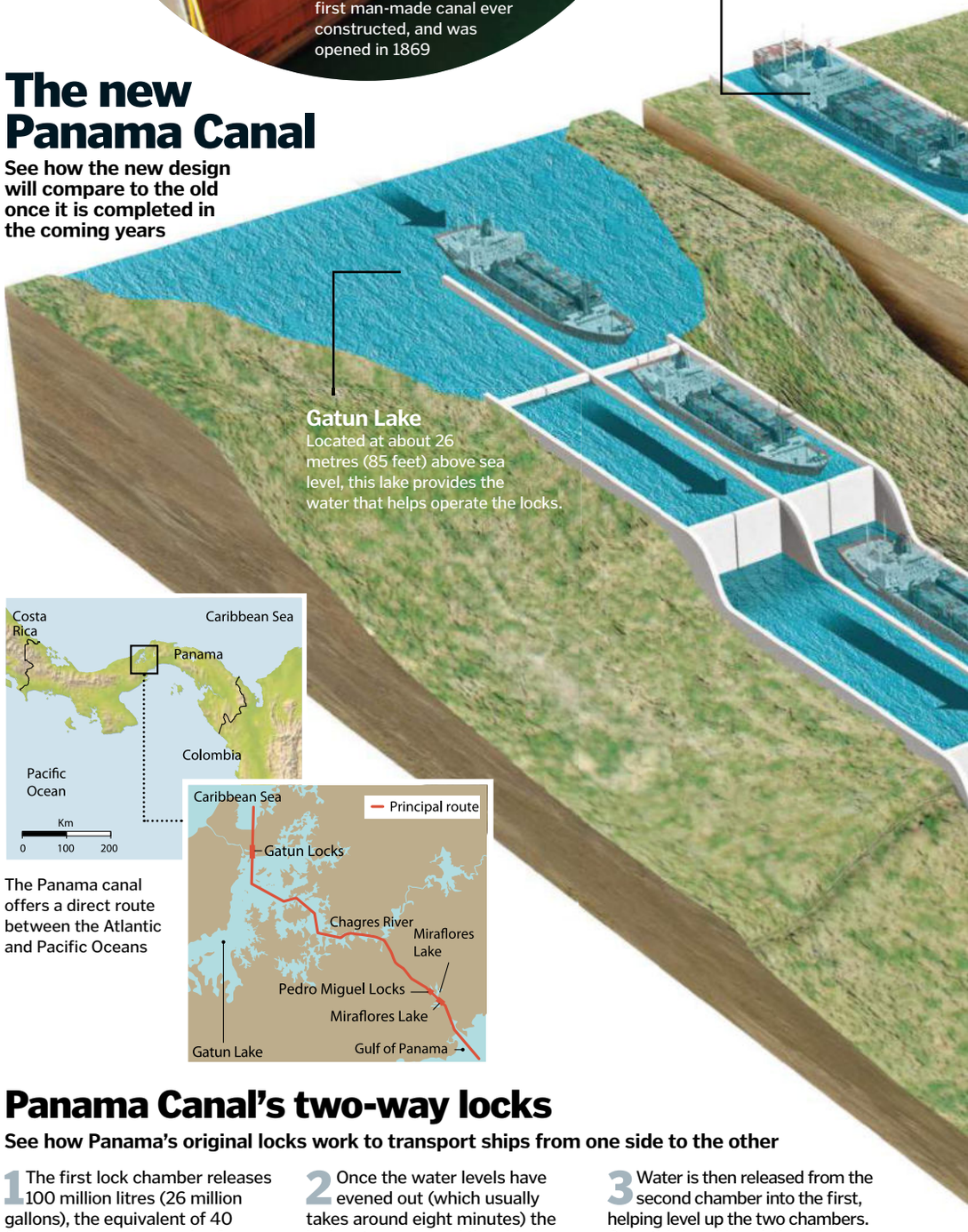
The renovations were scheduled to be completed in 2015, but a considerable number of issues have resulted in delays. Nevertheless, the canal's improvements will have a huge impact; trade will become more efficient as it will require less time, money and fuel to get products to American ports. Much of the intercontinental traffic will no doubt flock to Panama to take advantage of this, boosting American economy much like it did when it opened in 1914.



The Suez Canal was the first man-made canal ever constructed, and was opened in 1869

## The new Panama Canal

**See how the new design will compare to the old once it is completed in the coming years**



**Increased traffic**
Once the renovations are finished, the volume of cargo transported annually through Panama will double to 600 million tons.

**Gatun Lake**
Located at about 26 metres (85 feet) above sea level, this lake provides the water that helps operate the locks.





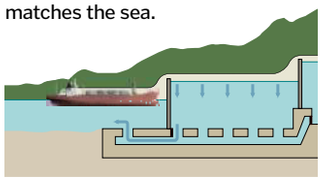


The Panama canal offers a direct route between the Atlantic and Pacific Oceans

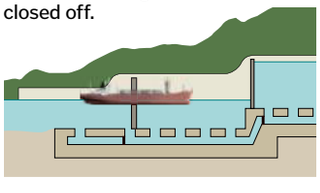
## Panama Canal's two-way locks

**See how Panama's original locks work to transport ships from one side to the other**

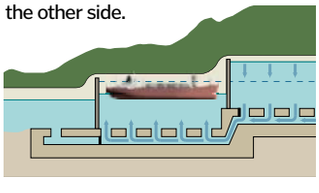
1 The first lock chamber releases 100 million litres (26 million gallons), the equivalent of 40 Olympic swimming pools of freshwater into the ocean, levelling out the water level so that it matches the sea.



2 Once the water levels have evened out (which usually takes around eight minutes) the lock gates open and the ship is able to enter the first chamber. The valves and gates are then closed off.

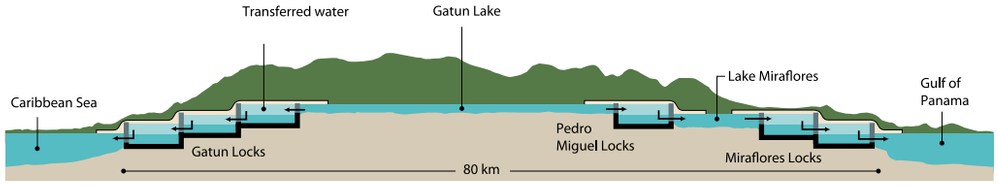


3 Water is then released from the second chamber into the first, helping level up the two chambers. Once this is achieved, the ship can enter the second chamber. This process continues until it reaches the other side.



### Reusable water
60 per cent of the water drained from each new chamber will be reused, making the new locks much more efficient and eco-friendly.

### Deeper channels
Extensive dredging of the current canal will make it significantly deeper, helping it to accommodate much larger vessels.




# Competition for Panama?

The Panama Canal is starting to face fierce competition from around the world. Egyptian president Abdel Fattah el-Sisi announced plans to add an extra lane to the Suez Canal, which runs through Egypt to connect the Mediterranean Sea with the Red Sea, in 2014. It was completed in a third of the originally estimated time and has allowed two-way traffic, doubling the canal's capacity to an average of 97 ships each day. It has also slashed transit time almost in half, from 18 hours to 11.

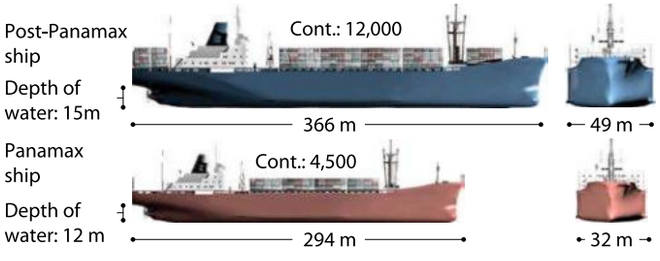
The Suez is not the only canal trying to get in on the action; there is likely to be a new contender in the coming years. One Chinese entrepreneur has announced plans for a £33 billion ($50 billion) Nicaragua Grand Canal, which would connect the Atlantic to the Pacific through Lake Nicaragua. This canal would be 278 kilometres (173 miles) long and able to accommodate some of the biggest ships in the world, carrying enormous containers. Construction is planned to take five years, but at the time of writing it has not yet started.

### Fast transit time
The canal is 82 kilometres (51 miles) long, and allows ships to go from the Atlantic to the Pacific in just over eight hours.

### Global significance
Roughly three per cent of world maritime commerce flows through Panama Canal, which will no doubt rise when the new locks open.

### Wider locks
The new locks will be 55 metres (180 feet) wide, allowing the gigantic Post-Panamax ships through the canal.

### Excellent safety
There have only been 38 shipping accidents reported since 2002, an average of one per 4,000 voyages via the canal.



# Airless tyres

## Will Michelin's new airless tyre design end the fight against flat tyres?

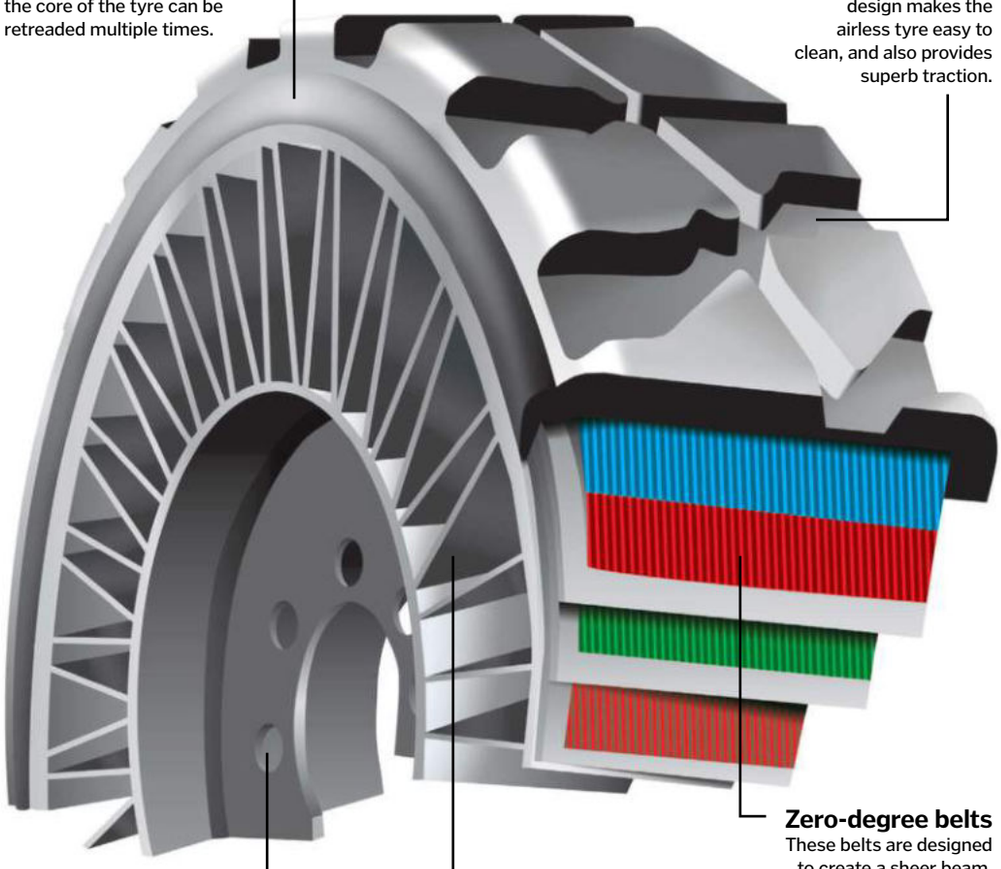
Michelin's airless tyre design promises to put an end to frustrating slow punctures and dangerous high-speed blow-outs. Their new 'Tweel' is a combined wheel and tyre assembly in a single, tough unit, primarily designed for commercial use in landscaping, agriculture and construction. If successful, the designers hope to implement the technology in other vehicles.

Solid, air-free tyres have existed for a while but as they are incredibly hard, the vehicle bounces when travelling over rough terrain. The Michelin Tweel combats this by compressing when driving on rugged roads. Another advantage is that it's much more eco-friendly than current air-filled pneumatic tyres, as it is made of a plastic resin that can be repeatedly recycled. This means these tyres will have very little environmental impact even when they are replaced.

We are many years from seeing this type of wheel design on road cars, but the prospect of flat tyres becoming a thing of the past will excite all motorists.

## Inside an airless tyre

**See the features that make the Tweel so durable**



**Undertread**
A thick undertread means the core of the tyre can be retreaded multiple times.

**Open tread**
The deep open tread design makes the airless tyre easy to clean, and also provides superb traction.

**Zero-degree belts**
These belts are designed to create a sheer beam, which helps to direct the load in a consistent path towards the strongest part of the tyre.

**Strong spokes**
The tyre's polyresin spokes help make the ride more comfortable by reducing the amount of bounce when driving.

**Great compatibility**
Each tyre is fitted with eight-hole steel hub bolts, allowing them to fit all standard skid-steer machines.

# How do parking meters work?

## Find out how these dreaded machines police our parking 24 hours a day

Since the first parking meter was installed in Oklahoma in 1935, they have spread throughout the world, as cars became the dominant mode of transport. In the UK alone, parking meters provide revenue in the region of £500 million ($762 million) each year, just from on-street parking.

For cash payments, the meter identifies each inserted coin by conducting a set of pre-programmed tests, which include weighing the coin and testing its physical properties using electrical currents or lasers. This helps to distinguish between the different types of metal used to create the coins.

In America, the process is often simplified by accepting only one type of coin, most commonly the quarter. Parking meters in the US commonly only monitor one space; modern versions do this with the help of special sensors that use lasers to determine when the space has been vacated. Once it is vacated the clock is automatically reset to zero, so that another car can't use someone else's parking time for free. Individual parking meters are largely being replaced by modern pay-and-display meters, as they take up less space and can be powered by solar energy.

More and more parking meters are now accepting electronic payments, and some even use pre-loaded smart cards

The Immortus will be a 40kW composite roadster, weighing around half a ton

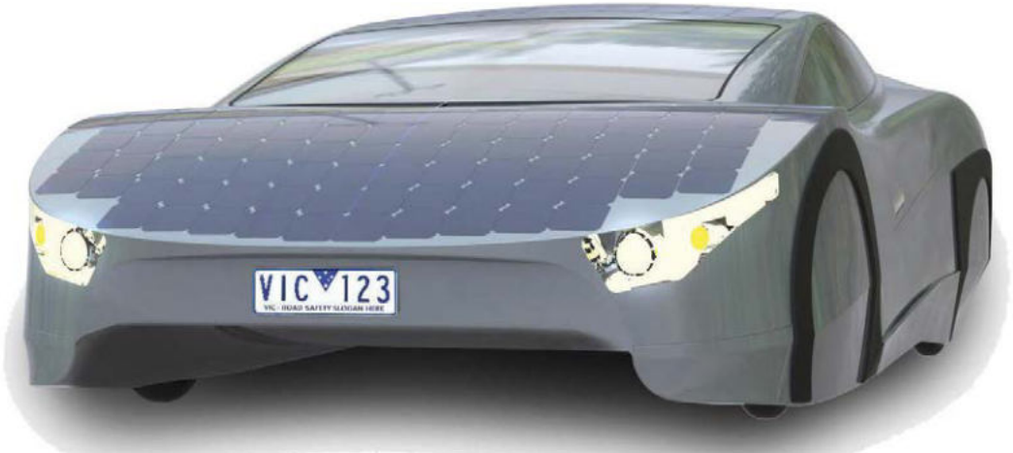
# Solar powered cars

## Inspired by post-apocalyptic movies, the Immortus can drive on sunshine alone

This limited edition, solar-electric sports car is the brainchild of a small electric vehicle company called EVX, which is currently working on a prototype that should be ready by the end of 2016. The car will absorb the Sun's energy via almost seven square metres (75 square feet) of photovoltaic cells spread across its roof, and will also feature a plug-in electric powertrain, complete with a lithium-ion battery pack. Measuring five by two metres (16.4 by 6.6 feet) it will be by no means small, with enough room for two occupants plus hand luggage.

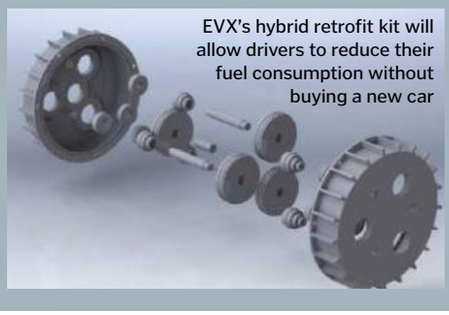
By combining a fully charged battery and the Sun's rays, the Immortus will have a range of over 550 kilometres (342 miles) when travelling at 85 kilometres (53 miles) per hour. However, if you slow the average speed down to 60 kilometres (37 miles) per hour, it will be possible for the Immortus to keep going all day, limited only by the availability of sunshine. Its ability to store power while in motion will be hugely significant, helping it to deliver excellent performance when needed, reaching a top speed of over 150 kilometres (93 miles) per hour with combined electric and solar energy.

There is still much work to be done before the Immortus can become a reality; EVX are seeking funding of almost £1 million ($1.5 million) in order to start production. Once they have obtained this funding they are expected to make only 100 units, which will retail for an estimated £326,000 ($500,000). At least prospective buyers will save on fuel!




### Inspiring future technology

While designing the solar car technology that will feature in the Immortus, EVX have identified several innovations that could be incredibly useful to car manufacturers around the world. One such technology is a hybrid retrofit kit, which will convert petrol-powered vehicles into plug-in hybrids, giving owners the ability to make older cars environmentally friendly. This kit will also increase acceleration after breaking and turn conventional two-wheel drive cars into four-wheel drive. EVX have also theorised a lightweight, air-cooled battery box, which is essential for the Immortus and could soon be applicable to the aeronautic and mining industries, as they are likely to rely on electric technology in the future. The designers also want to develop small cameras to replace wing mirrors, as this will reduce air resistance and make future electric cars even more efficient.



EVX's hybrid retrofit kit will allow drivers to reduce their fuel consumption without buying a new car

# CURIOSITY'S GREATEST DISCOVERIES

## The most sophisticated rover sent to another planet has found that Mars was once habitable

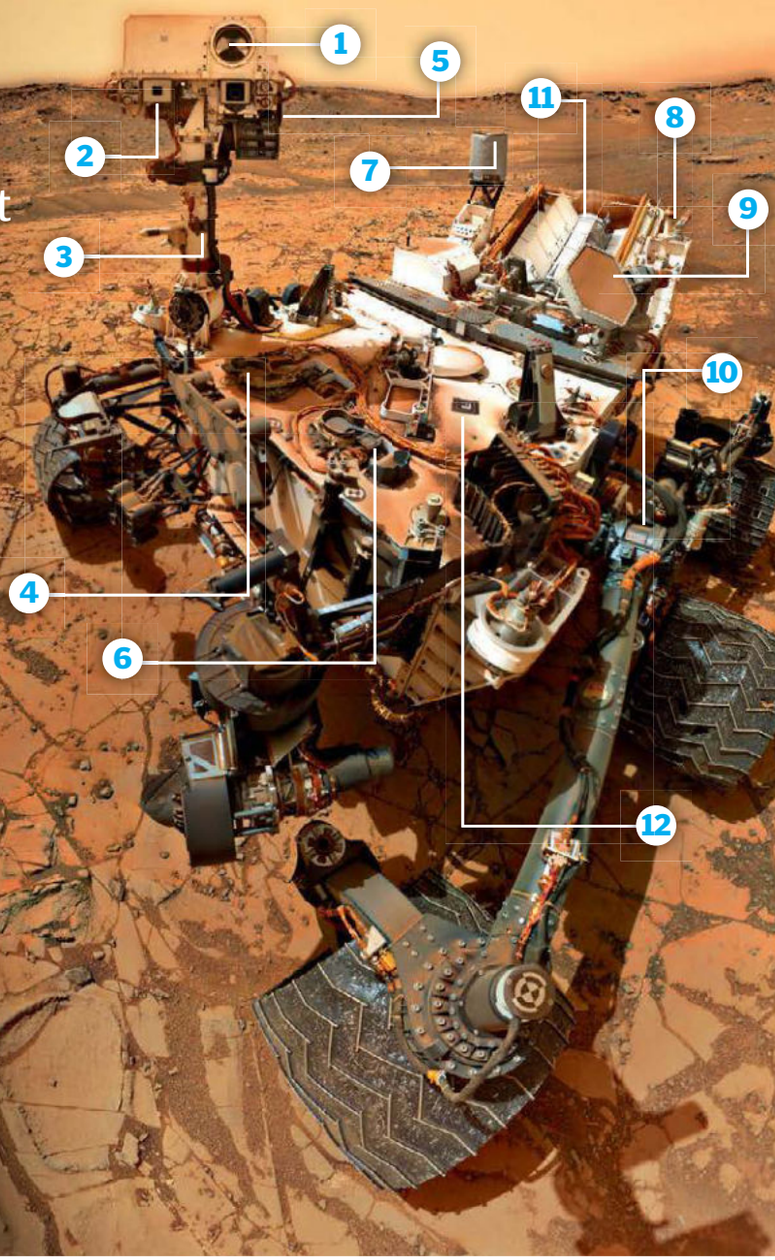
Today Mars is dry, cold and barren. No water flows on its surface and the air is thin and poisonous. But once upon a time, Mars was wet, possibly warm and could even have been home to microbial life.

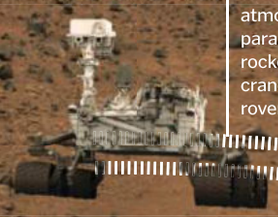
In 2004, NASA landed two robotic rovers called Spirit and Opportunity on Mars, and found conclusive evidence that water once ran on Mars' surface, perhaps as recently as a few million years ago. What scientists wanted to know next was whether this water contributed to an environment that could support life, so they sent another rover, the largest ever sent into space, to answer that question.

Curiosity is about the size of a family car. It is controlled by engineers back on Earth, whose commands can take up to 20 minutes to travel to Mars. Curiosity's computer brain uses software called AEGIS to identify objects of interest and to avoid hazards, such as steep slopes, large boulders or ditches, without scientists on Earth interfering.

Curiosity's rocker-bogie suspension system allows it to climb over obstacles while keeping all six of its wheels on the ground. The rover has 17 'eyes' – a system of cameras that can capture a three-dimensional map of the terrain within three metres (ten feet), which helps Curiosity judge the distance to obstacles in its way.

These technological innovations help support Curiosity's scientific goals. These include finding the chemical building blocks of life, investigating the mineralogy of the Martian surface and measuring radiation and other conditions in the atmosphere.

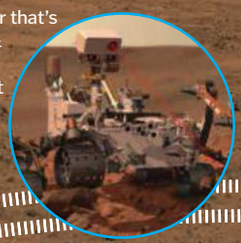


*6 August 2012*
**Arrival on Mars**
Curiosity's daredevil landing is dubbed 'seven minutes of terror', featuring atmospheric entry, parachutes, retro rockets and a 'sky crane' to lower the rover to the surface.

*10–13 August 2012*
**Brain transplant**
New software, uploaded during the rover's flight to Mars, is installed to make Curiosity better at spotting hazards as it drives along.

*19 August 2012*
**Laser power**
Curiosity uses the laser that's part of its Chemistry & Camera (ChemCam) instrument for the first time to analyse the composition of a basaltic rock called 'Coronation'.



*22 August 2012*
**On the road**
Curiosity sets off, driving around and exploring its landing site, known as 'Bradbury Landing'.

**1 ChemCam**
This laser zaps a target such as a rock, heats it and creates a burst of vapour. ChemCam then studies this vapour and identifies elements within it.

**2 Navcams**
A stereo pair of cameras provides a view of the landscape to aid navigation.

**3 REMS**
The Rover Environmental Monitoring Station (REMS) is a weather station, able to measure temperature, air pressure and wind speed.

**4 SAM**
The Sample Analysis at Mars (SAM) instrument suite looks for the chemical building blocks of life in rock and dirt samples.

**5 Mastcam**
The Mastcam takes colour video and images of the terrain, stitching them together to create panoramas.

**6 CheMin**
The Chemistry and Mineralogy instrument (CheMin) analyses various Martian minerals.

**7 UHF antenna**
The ultra-high frequency antenna sends all the data and images back to scientists on Earth.

**8 DAN**
The Dynamic Albedo of Neutrons (DAN) instrument looks for the presence of water.

**9 High-gain antenna**
Commands are uplinked to the rover via the high-gain antenna on a daily basis.

**10 MARDI**
The Mars Descent Imager (MARDI) took images of the surface to direct Curiosity to a safe landing.

**11 RTG**
The radioisotope thermoelectric generator (RTG) uses plutonium fuel to produce the electricity Curiosity needs.

**12 RAD**
The Radiation Assessment Detector (RAD) measures and identifies any high-level radiation.

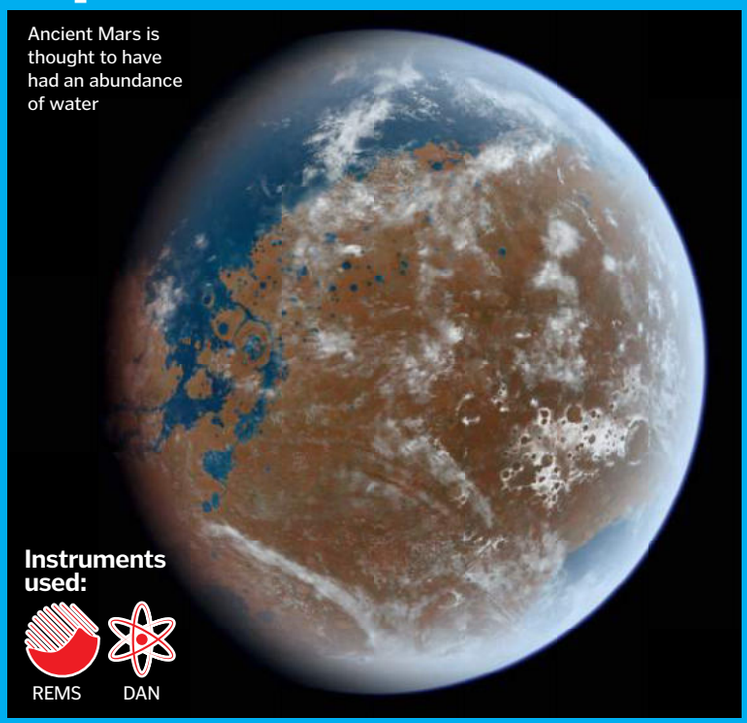
## Mars could have supported life

The view from within Yellowknife Bay

Is there, or has there ever been, life on Mars? That's the big question. Scientists think that the Red Planet is lifeless now, but in the past it could have had a climate that would have supported microbial life. The evidence for this comes from 'tasting' the minerals and elements contained within the dirt and in old rocks that formed when Mars may have been habitable. Curiosity has found the likes of sulphur, nitrogen, hydrogen, oxygen, phosphorous and carbon in Martian rock. Some of these, like sulphur and hydrogen, are 'food' for microbes, oxygen is a possible by-product, while carbon, nitrogen and phosphorous are important building blocks for cells and DNA. Curiosity found these by sampling sedimentary rock in a region called Yellowknife Bay, where results indicate that liquid water was once present.

**Instruments used:**
SAM CheMin

## Liquid water exists below the surface



Ancient Mars is thought to have had an abundance of water

**Instruments used:**
REMS DAN

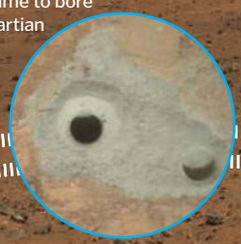
The rovers Spirit and Opportunity were able to determine that rivers ran on Mars over 3.5 billion years ago and were the result of a thicker atmosphere, meaning Mars was once warmer and had a higher surface pressure. Curiosity has found that its landing site used to be a freshwater lake and that water played a major role in creating conditions suitable for microbial life.

Much of that water has since been lost to space, but there is still plenty on Mars. Most of it is locked up as ice in the polar caps, or as permafrost just below the dusty surface, stretching all the way from the poles to the mid-latitudes. However, recently Curiosity discovered evidence that water could still exist in a liquid state below the surface. Scientists speculate that the water would be kept liquid by being mixed with perchlorate salts, which could act like an anti-freeze down to around -70 degrees Celsius (-94 degrees Fahrenheit).

*27 September 2012*
**Old streambed**
Curiosity finds evidence for an ancient, gravelly streambed, where water flowed billions of years ago.

*30 October 2012*
**Minerals**
Analysis of the Martian dirt finds it is filled with volcanic minerals, similar to the basaltic soils of Hawaii.

*9 February 2013*
**Drilling**
Curiosity used its drill for the first time to bore into some Martian bedrock and retrieve a sample for study.



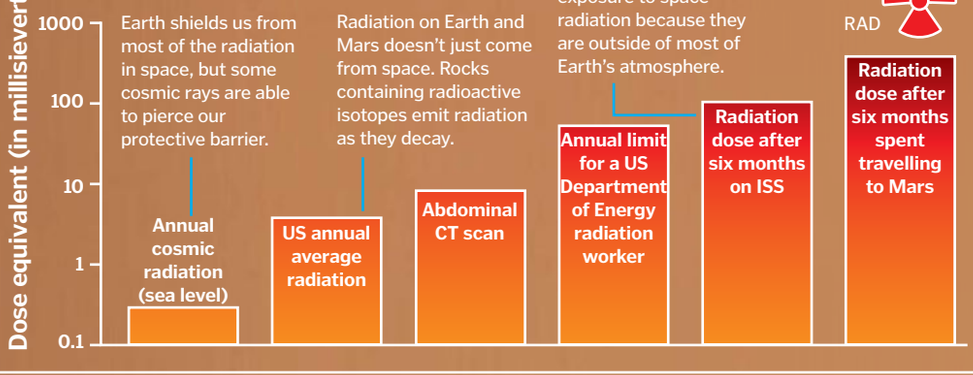
*12 March 2013*
**Conditions for life**
By studying the bedrock samples, scientists find elements such as oxygen, phosphorous and carbon, which could have supported microbial life on Mars in the distant past.

*6 June 2013*
**Long-distance driving**
After exploring, Curiosity prepares to switch to distance-driving mode to begin the long trek towards its primary destination: Mount Sharp.

## Radiation could endanger humans

Mars is a dangerous world for humans, and one of the challenges that astronauts will face when they finally land on the Red Planet is coping with the radiation from space. Unlike Earth, Mars does not have a thick atmosphere or a magnetic field to deflect away radiation, which mostly comes from the Sun, or from cosmic rays. However, Curiosity's Radiation Assessment Detector (RAD) has found that the exposure on the surface is not as bad as in space. During the first 300 days of the mission, RAD measured the daily radiation dose to be 0.67 millisieverts per day. In space the daily dose is 1.8 millisieverts, meaning astronauts are most at risk when travelling between Earth and Mars.

### Radiation levels




# Mars was once warm and wet

Instrument used: SAM

Mars once had a much thicker atmosphere than it does now, providing the surface pressure and warmth for liquid water to exist. However, over billions of years, Mars' atmosphere has been lost, as the planet's gravity has not been strong enough to hold onto it. In particular, solar wind has stripped away the upper layer of the atmosphere.

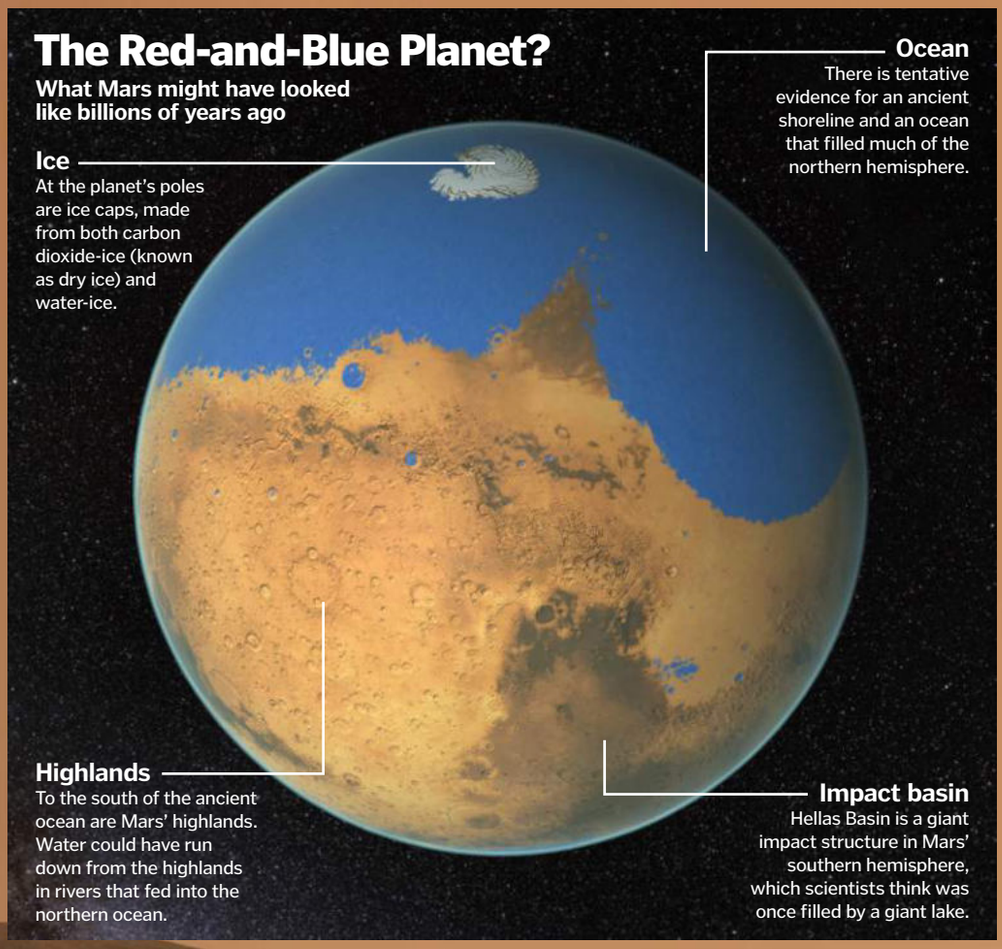
Curiosity has been able to determine the rate of loss of Mars' atmosphere by measuring xenon gas in the atmosphere. Xenon can exist as different isotopes – versions containing different numbers of neutrons – and the ratio of these isotopes changed as some were preferentially removed from the atmosphere.

Similarly, scientists have calculated that Mars has lost 87 per cent of its water by comparing the ratio of normal water, with oxygen and hydrogen atoms, to 'heavy' water, with oxygen and deuterium atoms. Normal water is lighter, so escapes more easily.

Gravel and rounded pebbles, embedded in sedimentary bedrock, are evidence for the action of water

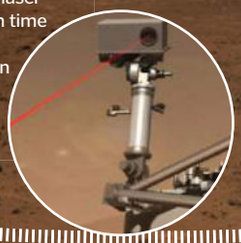
### The Red-and-Blue Planet?

**What Mars might have looked like billions of years ago**




**6 August 2013**
**A year on Mars**
Curiosity celebrates a year on Mars, having returned almost 24 gigabytes of data to Earth, 36,700 images and driven a total of 1.6 kilometres (one mile).

**5 December 2013**
**100,000 zaps**
Curiosity fires its laser for the 100,000th time – an indication of how busy it's been since the rover landed!

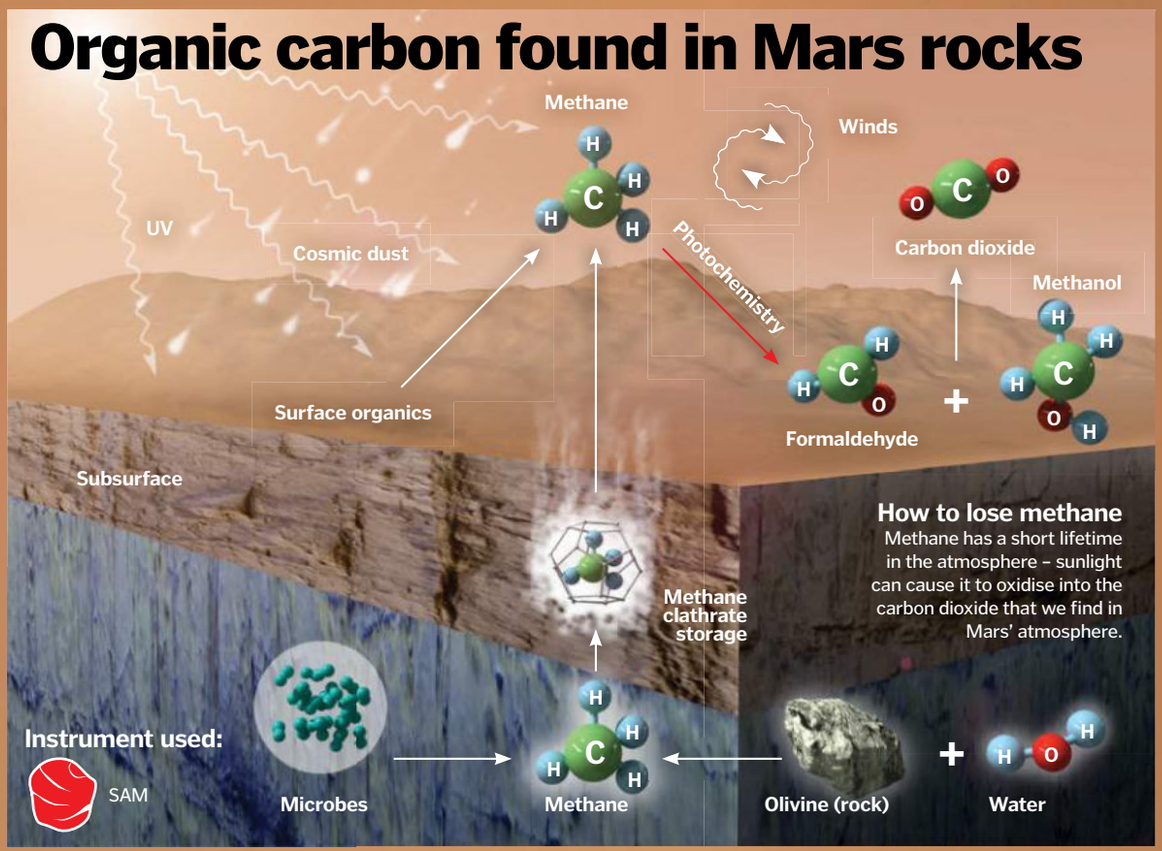


**9 December 2013**
**Radiation warning**
After measuring the radiation on Mars for over a year with Curiosity, scientists reveal that astronauts on the surface will receive less than half the radiation exposure they will get in space.

**24 June 2014**
**A Martian year**
Curiosity completes a full Martian year, which is 687 Earth days, on the surface of the Red Planet.

**11 September 2014**
**Mount Sharp**
After driving for 15 months, Curiosity finally arrives at the slopes of Mount Sharp.

# Organic carbon found in Mars rocks




Organic molecules and compounds, which are materials that contain carbon and are very useful for life, have been found in Martian rocks. The rover used its drill to dig into a rock that has been nicknamed 'Cumberland' and then sampled some of the powder produced by the drilling. Unfortunately however, Curiosity has been unable to identify the exact nature of the organic molecules in the powder because their chemical structure was altered when they were heated by the SAM instrument.

However, one example of an organic molecule, methane, has been detected by Curiosity. On two occasions, once during late 2013 and again early in 2014, the rover detected a spike in methane levels in the atmosphere. Methane is short-lived in the atmosphere, so had to be being produced relatively nearby. Living things can produce methane, but it can also result from geological processes too. At the moment the jury is still out on the origin of the methane; a geological origin is the most likely, but scientists cannot yet rule out the possibility that the methane is being produced by microbes. If it is, then that would be an astounding discovery.

### Methane
A methane molecule is formed from one carbon atom and four hydrogen atoms.

### Wind action
It is thought that methane is distributed across the Red Planet by Martian winds.

### Underground
Methane may be trapped in icy lattices called clathrates. When the clathrates melt due to seasonal temperature changes, the methane leaks out through cracks and vents.

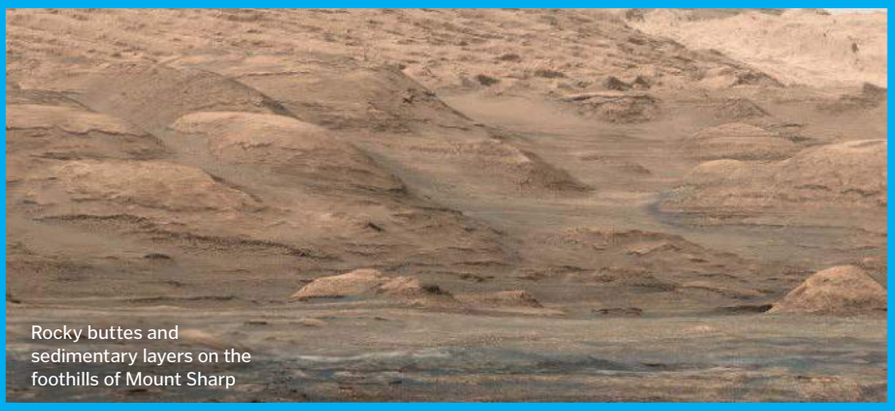
### Geology
Geological action can also create methane. Liquid water under the surface can react with the mineral olivine, found in rocks, to create methane.

### Ultraviolet
UV light from the Sun could produce methane by inducing reactions with either organic material on the surface or in cosmic dust falling through the atmosphere.

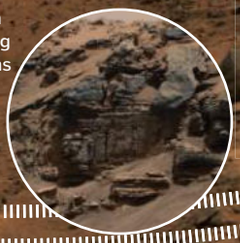
### Biological process
Martian methane could potentially be created by biological processes, a result of being generated by tiny microbial life-forms.

## What's next for Curiosity?

When Curiosity landed in the giant 154-kilometre (96-mile) wide Gale Crater, its central mountain, Mount Sharp, which is 5.5 kilometres (3.4 miles) tall, was always going to be an attractive destination. In September 2014, Curiosity arrived at the foothills of Mount Sharp, just over two Earth years after landing on Mars. Now its mission is to travel around the lower parts of the mountain, occasionally sampling sedimentary rock to determine more about the geological and chemical history of the area. The way the mountain is made of sediments that were laid down means that the oldest layers, dating back perhaps over four billion years, are found at the bottom. The aim will be to try and determine at what point the environment around the mountain turned from a freshwater lake into more acidic conditions, before drying up completely.


Rocky buttes and sedimentary layers on the foothills of Mount Sharp

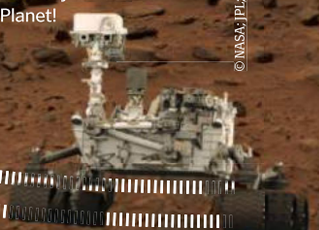
*8 December 2014*
**How water shaped a mountain**
Curiosity finds sedimentary layers in Mount Sharp, showing that the mountain was built gradually in a deep lake that filled Gale Crater.



*16 December 2014*
**Methane**
Curiosity detects a ten-fold spike in methane in the atmosphere surrounding it – but is it geological, or could it have a biological origin?

*24 March 2015*
**Nitrogen**
After heating a sample of sedimentary material from Mount Sharp, Curiosity detects biologically useful nitrogen in the form of nitric oxide.

*5 August 2015*
**Three years on Mars**
The Curiosity rover celebrates its third 'landiversary' on the Red Planet!



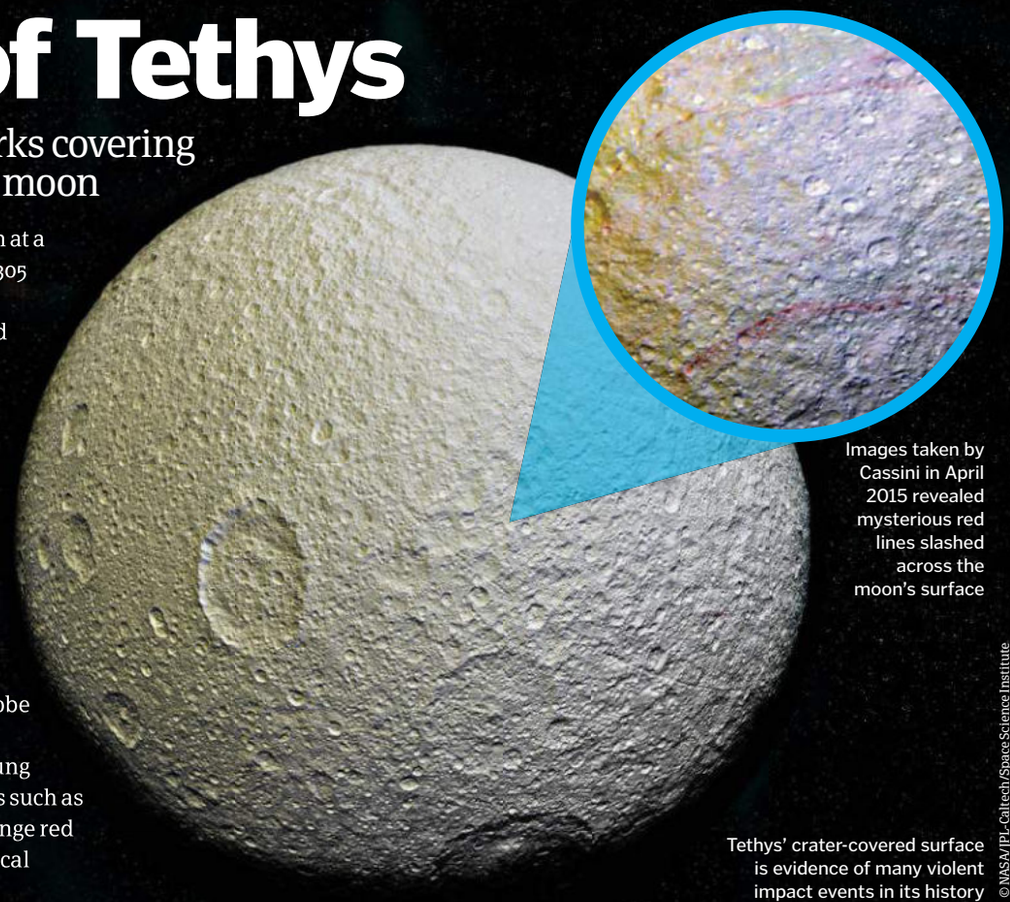
# Icy scars of Tethys

## The craters and mysterious marks covering the surface of Saturn's battered moon

Composed mainly of ice, Tethys orbits Saturn at a distance of around 295,000 kilometres (183,305 miles). It is the fifth largest of all of Saturn's satellites and has two tiny companions, Telesto and Calypso, which are both less that 32 kilometres (20 miles) across, held in place by Tethys' gravity. It is merely one of 62 moons orbiting the ringed planet, but it has a compelling story.

Tethys has taken an unprecedented number of hits during its lifetime, which have given it an almost sponge-like appearance. It has a particularly noticeable crater known as Odysseus, which covers nearly five per cent of the entire moon's surface – which is equivalent to a crater bigger than Russia on Earth.

Enhanced-colour images from NASA's Cassini probe have recently highlighted scar-like red arcs across Tethys' surface. These marks must be relatively young because they seem to have formed over old features such as craters. Scientists are not sure what causes the strange red colour, but one theory is that it's the result of chemical impurities in the ice.



Images taken by Cassini in April 2015 revealed mysterious red lines slashed across the moon's surface

Tethys' crater-covered surface is evidence of many violent impact events in its history

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# Meteorological satellites

## The spacecraft keeping a watchful eye on Earth to help us predict the weather

Weather forecasting isn't just handy for letting you know if you need an umbrella, it can also help save lives by providing early warning of devastating storms and floods. To be able to accurately predict these events, forecasters need to constantly monitor the Earth's surface and atmosphere, and they can do this thanks to a vast network of meteorological satellites flying through space. There are two main types: geostationary and polar-orbiting satellites, which work together to monitor the planet from every angle. Currently watching North and South America and the Eastern Pacific are the Geostationary Operational Environmental Satellites, GOES-EAST and GOES-WEST. In 2016, the current GOES-EAST satellite, GOES-13, will retire after ten years of service. Its replacement, GOES-R (to be renamed GOES-16 after launch), will be able to provide 50 times more information, helping forecasters predict the weather more accurately than ever before.

### The statistics...

**GOES-R specs**

**Weight:** 2,800 kilograms (6,173 pounds)

**Orbital altitude:** 35,406 kilometres (22,000 miles)

**Launch date:** 2016

**Launch vehicle:** Atlas V 541

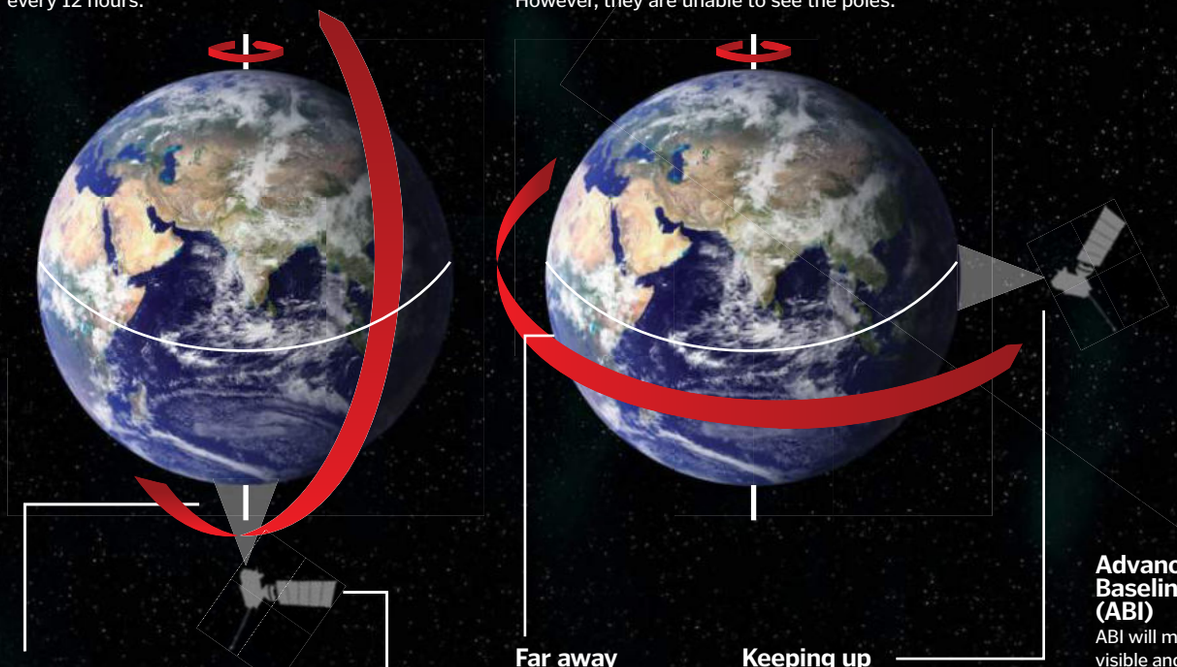
*"Weather forecasters need to constantly monitor the Earth's surface and atmosphere"*

## Polar orbit

Polar-orbiting satellites circle the Earth over the North and South Poles, reaching each one every 90 to 100 minutes. As the Earth rotates beneath them, each satellite passes over the same geographic point twice a day, providing full coverage of the planet every 12 hours.

## Geostationary orbit

Geostationary satellites circle the Earth above the equator and move at a particular speed in order to match the planet's rotation. This enables them to 'hover' over a fixed geographic point on the Earth's surface and provide continuous data for that area. However, they are unable to see the poles.



**Close by**
Polar-orbiting satellites have a close-up, detailed view of Earth from an altitude of around 850 kilometres (530 miles).

**Top speed**
A velocity of only around 7.5 kilometres (4.7 miles) per second is needed to complete polar orbits.

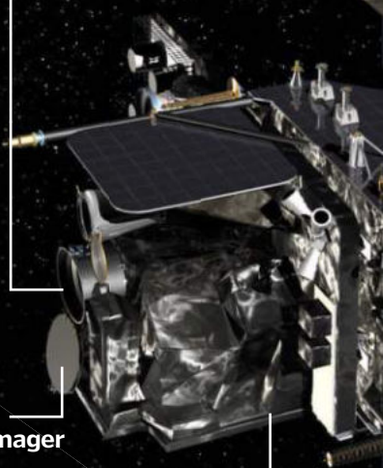
**Far away**
Located at an altitude of around 35,800 kilometres (22,245 miles), geostationary satellites have a very distant view of Earth.

**Keeping up**
The satellite must travel at about 11,000 kilometres (6,835 miles) per hour in order to remain over a fixed point on Earth's surface.

## Next-generation weather satellite

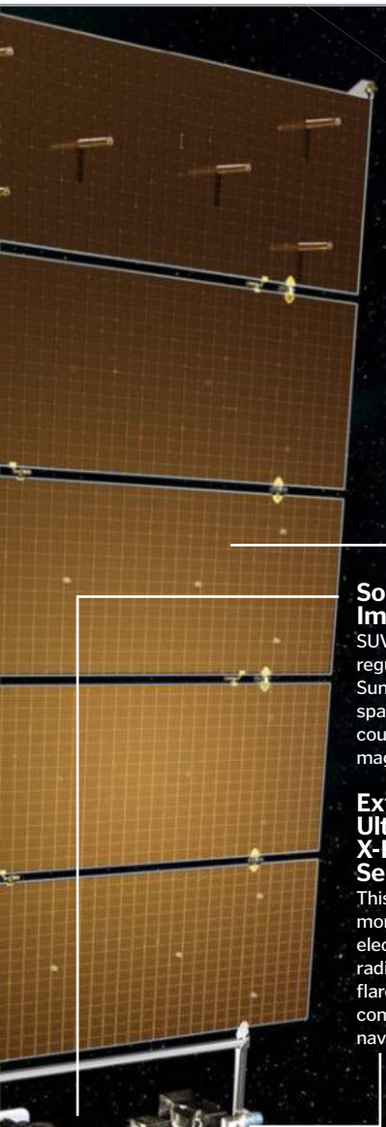
**How GOES-R will monitor the weather in amazing detail**

**Geostationary Lightning Mapper (GLM)**
By monitoring the presence of lightning, GLM will provide early predictions of storms and other severe weather events.



**Advanced Baseline Imager (ABI)**
ABI will measure the visible and infrared light reflected by the Earth to monitor the planet's clouds, atmosphere and surface.

**Star tracker**
By pinpointing its location based on the position of the stars, the satellite's thrusters can then manoeuvre it in orbit.



**Solar array**
Five separate solar panels will deploy into a single, rotating wing to provide electricity for the satellite's instruments.

**Solar Ultraviolet Imager (SUVI)**
SUVI will create regular images of the Sun to help us forecast space weather that could disturb Earth's magnetic field.

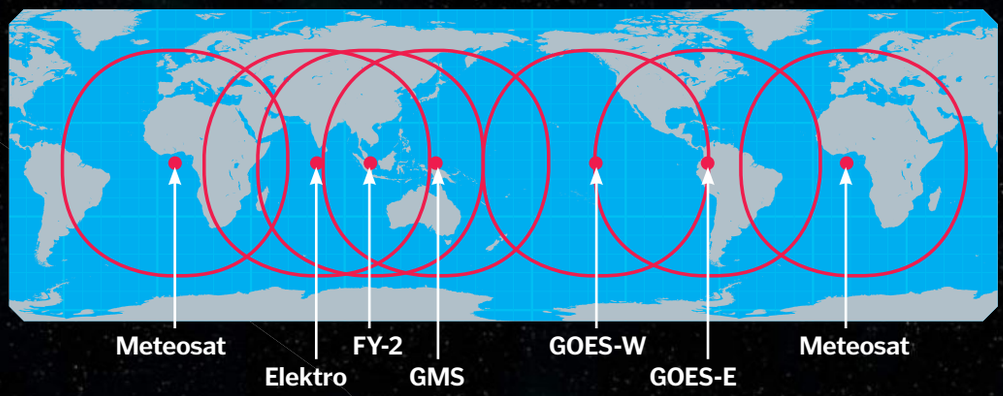
**Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS)**
This instrument monitors the Sun's electromagnetic radiation to detect solar flares that can interrupt communication and navigation systems.

**Space Environment In-Situ Suite (SEISS)**
Four sensors monitoring proton, electron and heavy ion fluxes in space will highlight any radiation hazards to astronauts and spacecraft.

**Unique Payload Services (UPS)**
A series of transponders will communicate with other satellites and Earth-based platforms for more geographically complete monitoring.

**Antennas**
The data collected by GOES-R will be sent back to Earth for processing via a series of antennas.

**Magnetometer**
Used to measure Earth's magnetic field, this instrument will be able to detect charged particles that can be dangerous to spacecraft.



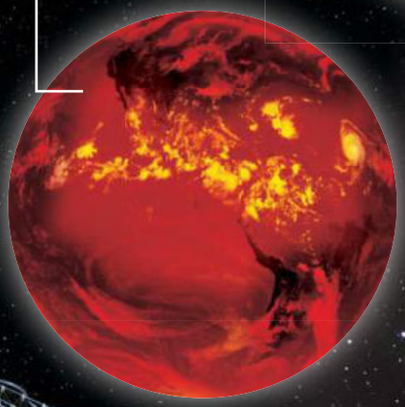

# Active satellites

Each meteorological satellite can only monitor one area of the Earth's surface at a time, with those in geostationary orbit sticking with one spot, and the polar-orbiting variety continuously changing theirs. Therefore, to make sure that as much of the Earth's surface is under constant observation as possible, a team of satellites work together to create the bigger picture. The polar-orbiting satellites currently in operation include Europe's MetOp, Russia's Meteor, China's Fengyun and the NOAA series, launched by the US. The different geostationary satellites currently being used, and the areas they cover, can be seen on this map (above).

**Combined**
Combing visible and infrared data helps show Earth's features and their temperatures in greater detail.

**Visible**
The clouds reflect more light and so appear brighter than the land and sea.

**Infrared**
Features with hotter temperatures appear darker whereas cold areas are bright.



# Imaging Earth

To monitor the presence of clouds, water vapour and surface features, meteorological satellites use radiometers to sense the electromagnetic radiation given off by the Earth. Two types of wavelength are picked up: visual and infrared. Visual light is reflected sunlight, so it is only available in daylight, whereas infrared light is heat, so it can be detected 24 hours a day.

# Space salad

## How to grow vegetables that are out of this world

Deliveries of fresh fruit and vegetables are rare on the ISS, so astronauts' diets mostly consist of pre-packaged, non-perishable foods. However, thanks to the Vegetable Production System, or Veggie, being used on board, this is starting to change.

The Veggie plant growth chamber uses plant pillows: small bags of slow-release fertiliser and a clay-like soil that is also used on baseball fields. These pillows are placed in a reservoir of water and have wicks inserted into them to draw the liquid into the soil. Plant seeds are glued onto these wicks to make sure they grow the right way up in the zero gravity environment – that the roots grow down into the soil and the shoots pop out the top of the pillows.

At the top of the chamber, LEDs provide light for photosynthesis as well as a sense of direction to keep the shoots growing upwards. A mixture of red and blue light is used as these are the colours of light plants use most, but the resulting purple hue makes the plants appear grey and unappetising. Therefore, to make their crops look more appealing, the astronauts can switch on additional green LEDs, which combine with the red and blue to create a more natural white light. The first Veggie crop was harvested in 2014 but it had to be frozen and returned to Earth for analysis to make sure it was safe to eat. Once approved for consumption, a second crop was grown and on 10 August 2015, the Expedition 44 crew became the first humans to sample space-grown produce.

## Veggie benefits

Growing vegetables on the ISS doesn't just have nutritional benefits for the crew; it can also improve their psychological wellbeing too. A bit of greenery provides some relief from the metallic, lifeless environment of the space station and allows the astronauts to form a connection with a living thing. This will be particularly important for the deep space missions to an asteroid, and then Mars, that NASA is currently planning. For small crews, living in a confined space with limited communication for an extended period of time, having a little piece of Earth to care for will help them cope with the stressful and isolated environment, as well as provide them with a sustainable food source. The tech used in the Veggie system is also proving useful much closer to home, with countries such as Dubai using it to maintain a controlled plant-growing environment in their hot and dry climates.

Growing plants in space has nutritional and psychological benefits for astronauts

Future spacecraft heading on deep space missions could have entire gardens on board



The first produce to be grown, harvested and eaten in space was red romaine lettuce

## The history of space food

**1962-1964**

The first space foods were pastes that were squeezed from tubes and cubes of dehydrated food that were rehydrated by saliva in the mouth.

**1965-1967**

NASA's Gemini missions had freeze-dried meals, including shrimp cocktail and butterscotch pudding, which were rehydrated by injecting water into the packet.

**1968–1972**

The Apollo missions were the first to have hot water, which made rehydrating food easier, and utensils in the form of spoons.

**1973-1979**

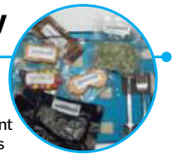
The Skylab space station had a dining table, onboard refrigeration, food warming trays and 72 different food items.

**1980-1999**

Astronauts on the Space Shuttle missions could design their own menus and heat their food in an onboard oven.

**2000-today**

On the ISS, the menu consists of frozen, refrigerated and ambient foods, and sometimes meals designed by celebrity chefs.



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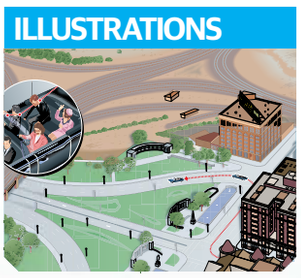



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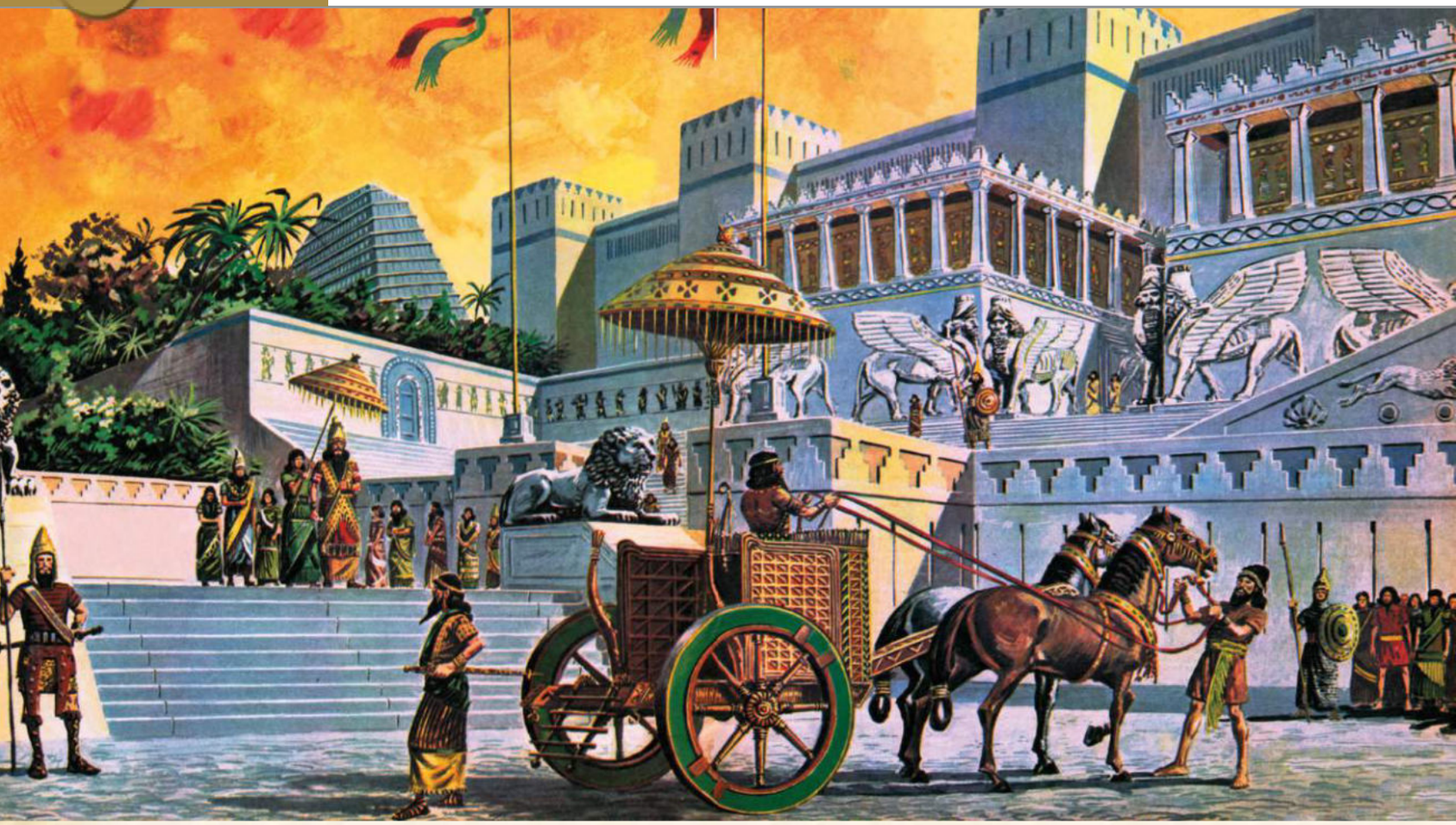


# MESOPOTAMIA
## THE CREATORS OF CIVILISATION

Discover how society as we know it began in a small region of modern day Iraq

The ancient region of Mesopotamia has fascinated, enthralled and perplexed historians and scientists for thousands of years. Mesopotamia was not like the ancient empire of Greece, or even Egypt, because it was not a united nation. Made up of a vast collection of varied cultures, city-states and beliefs, Mesopotamia was a land of multiple empires and diverse civilisations. It is perhaps thanks to this variety that Mesopotamia gave birth to what we recognise as civilisation today.

The list of Mesopotamian innovations is endless, and it is difficult to contemplate how modern life would be without them. Mesopotamia was home to the first ever cities, writing took form there and the oldest wheeled vehicles in the world were found in Mesopotamian ruins. Animals were domesticated, humanity came leaps and bounds in agriculture, innovative new tools were crafted, weapons were swung and wine was drunk. Mesopotamians were the first people to study the night sky, track the Moon and declare that there were 60 minutes in an hour, and 60 seconds in a minute.

Mesopotamia was driven by religion, and it was one of the few things that united the lands that made up the region. From this religion sprang customs, moral codes and social hierarchy. In many ways the Mesopotamians were ahead of their time, as women were regarded as individuals in their own right, free to own land, file for divorce and run businesses.

The Mesopotamian version of the Creation story declared that the world was formed when the gods achieved victory over the forces of chaos, and the same could be said in the creation of Mesopotamia itself. Mesopotamia, with its kings, taxes and trade, was a triumph of man's ability to conquer and thrive, and it set the blueprints for countless cities, countries and empires that followed.

SUMER

**5400 BCE**
The city of Eridu is founded; it is considered the first true city in the world.

**3600 BCE**
Writing first emerges in the form of cuneiform. Reeds are used to make marks in wet clay.

**3500 BCE**
Religion is first referenced in writing, in the form of Sumerian cuneiform tablets.

**2334-2218 BCE**
Sumer is conquered by Sargon the Great and comes under the rule of the Akkadian Empire.

# What it was like to live there

The word 'Mesopotamia' means 'between the rivers', which literally describes the location of the region. Mesopotamia lay between the Tigris and Euphrates rivers, which today flow through modern day Turkey, Iraq and Syria. All the regions of Mesopotamia experienced different geography, which led to variation in how people there lived. Lying between two rivers had some risks as the land was subject to frequent and unpredictable flooding, which could play havoc with farmers' crops. These floods went hand in hand with periods of drought. However, the swelling rivers helped to create very fertile soil that supported plants even with minimal rainfall, and allowed boats to be used as a quick means of transportation. Mesopotamians became skilled farmers and traded their crops for resources they were lacking, such as building materials like wood, metal and stone. The people took advantage of the ready supply of water by building canals to support the trade network and were able to flourish in spite of the lack of natural resources in some areas.

## ON THE MAP


## The land of plenty

**Mesopotamia's unique geography enabled cities and civilisations to rise from the ground**

**A perfect union**
Along with the Euphrates, the Tigris formed what is known as the 'Fertile Crescent'.

**The stone city**
For 50 years, Nineveh was the largest city in the world.

Tigris

Zagros mountains

Nineveh

Assur

**The centre of trade**
The city of Assur laid on a lucrative trade route.

Euphrates

**The source of life**
The Euphrates is the longest river in western Asia, at about 2,800km (1,740mi) long.

Babylon

The 'holy city'

**The first city**
Uruk was a place of firsts – writing, architecture and cities themselves.

Uruk

Ur

The port city

*"Mesopotamia, with its kings, taxes and trade, was a triumph of man's ability to conquer"*

# The rise of civilisation

**Three of the major cultures that arose in Mesopotamia and influenced society**

## SUMERIANS

Sumer was the southernmost region of Mesopotamia, comprising modern day southern Iraq and Kuwait. Sumer was first inhabited in approximately 4500 BCE, or possibly even earlier. It is in Sumer that the first cities in the world were established, starting with Uruk. Sumerians believed that their cities represented god's triumph over chaos.

## BABYLONIANS

Meaning 'gate of the gods', Babylonia lay in central southern Mesopotamia, which is modern day Iraq. The earliest days of Babylonia are a mystery lost to rising sea levels, but from 1792 BCE the famous king Hammurabi came into power and the city of Babylon - built upon the Euphrates river - became the beating heart of Mesopotamia.

## ASSYRIANS

Located in the Near East, the ancient kingdom of Assyria comprised of regions of Iraq, Syria and Turkey. Assyria was the driving force of technological, scientific and warfare developments in Mesopotamia. The Assyrian empire gradually expanded to unite most of the Middle East, increasing their power and wealth to become a formidable power in the region.



**2150-1400 BCE**
*The Epic of Gilgamesh* is written. The poetic work stands as one of the oldest pieces of western literature in existence.

**2100 BCE**
The Sumerian King List is created, establishing the idea of kingship as a divine institution.

**1800 BCE**
All the cities of Sumer, and of Mesopotamia, are united by Hammurabi, who makes Babylon his capital.

**1750 BCE**
A combination of invasion, migration and the sacking of Ur brings an end to the Sumerian civilisation.

# The world's first cities

## With a reliable source of food, people gathered together in Mesopotamia and formed the very first cities

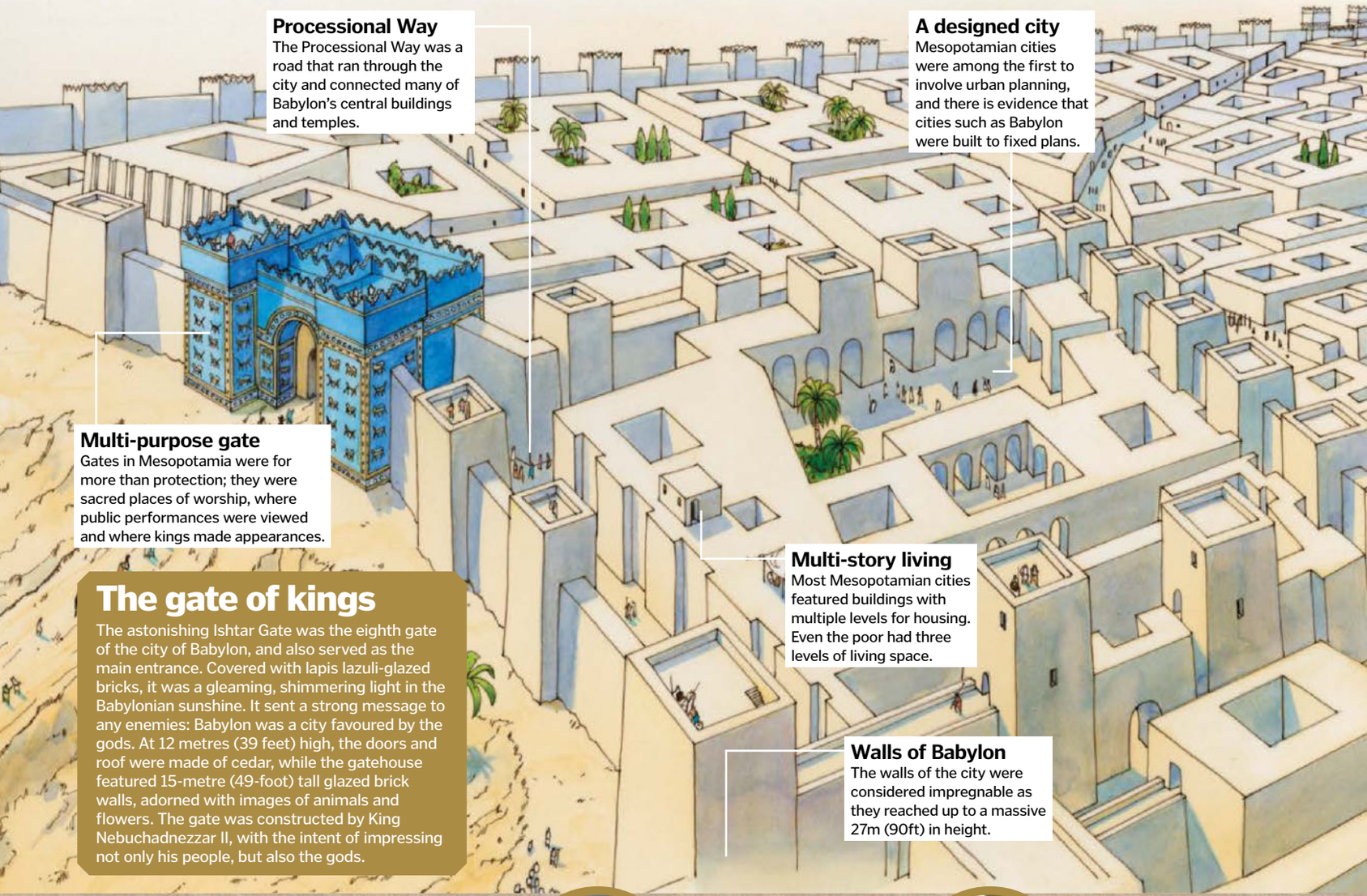
Mesopotamia was home to some of the very first cities in existence, leading many to link it to the birth of true civilisation. The origin of these cities is still unknown today, though many theories exist. One suggestion is that the development and building of temples created a place where people would gather, and thus served as points of contact between different groups of people.

Others believe that people sought sanctuary from natural disasters. As the Mesopotamians were able to develop technology to help them control the nearby rivers, such as levees, they could ensure a good crop. They had no need to be nomadic, and were able to settle in one place comfortably. It is for this reason that all the early cities were built along the two major rivers.

The moment the Sumerians began to form these cities, it forever altered human history. People went from being ruled by nature, to attempting to control it. By 4500 BCE the first recorded city rose in the form of Uruk. However, the only urban structure at this point was the temple, which regulated all economic and social matters.

The central purpose of these early cities was to help regulate trade, as southern Mesopotamia was reliant on outside resources. This need for trade and resources encouraged the spread of urbanisation. However, communication between the cities was difficult, and so each city developed into an individual city-state. This led to territorial disputes and, inevitably, war.

In order to keep their cities protected, the Mesopotamians built fortifications, and walled cities rose. Migration to these cities increased, and more buildings were erected. Cities gradually expanded and rulers were proclaimed, who then began looking outwards for trade and conquest.



**Processional Way**
The Processional Way was a road that ran through the city and connected many of Babylon's central buildings and temples.

**A designed city**
Mesopotamian cities were among the first to involve urban planning, and there is evidence that cities such as Babylon were built to fixed plans.

**Multi-purpose gate**
Gates in Mesopotamia were for more than protection; they were sacred places of worship, where public performances were viewed and where kings made appearances.

**Multi-story living**
Most Mesopotamian cities featured buildings with multiple levels for housing. Even the poor had three levels of living space.

**Walls of Babylon**
The walls of the city were considered impregnable as they reached up to a massive 27m (90ft) in height.

### The gate of kings

The astonishing Ishtar Gate was the eighth gate of the city of Babylon, and also served as the main entrance. Covered with lapis lazuli-glazed bricks, it was a gleaming, shimmering light in the Babylonian sunshine. It sent a strong message to any enemies: Babylon was a city favoured by the gods. At 12 metres (39 feet) high, the doors and roof were made of cedar, while the gatehouse featured 15-metre (49-foot) tall glazed brick walls, adorned with images of animals and flowers. The gate was constructed by King Nebuchadnezzar II, with the intent of impressing not only his people, but also the gods.

BABYLONIA

**1894 BCE**
The first Babylonian dynasty emerges; this Amorite dynasty forms a small kingdom including the city of Babylon.

**1792 BCE**
Hammurabi begins his reign as ruler of Babylon. He transforms it from a tiny town to a powerful city.

**1792-1750 BCE**
During his reign, Hammurabi introduces some of the earliest examples of laws in the form of the Code of Hammurabi.

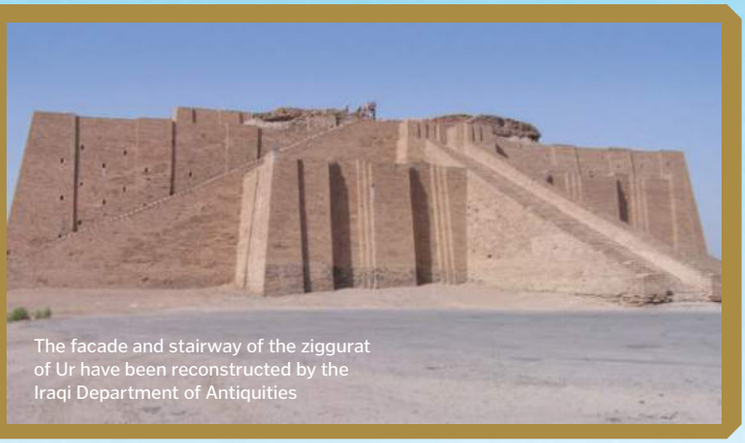
**1755 BCE**
Hammurabi conquers and unites Mesopotamia under his rule, and Babylon becomes known as a holy city.

# Towering temples

Ziggurats were temples built on high, stepped platforms. Although they originated in Sumerian cities in 2000 BCE, they gradually spread to all of Mesopotamia, including Babylonia and Assyria. The stepped towers were mainly constructed from sun-dried bricks layered between reeds. It is believed that many ziggurats featured a shrine at the top, but no examples of this remain.

Although their exact purpose cannot be verified, it is known that ziggurats were linked to religion, and each ziggurat was connected to large temple complexes. There was a belief in Mesopotamia that the gods resided in the Eastern mountains; therefore building high temples would more closely connect the people with god, linking heaven with Earth.

A practical purpose of the high platforms was to escape any rising floodwater that rushed into the lowlands. The structure of the ziggurat, which was accessible only by three stairways, also ensured that the rituals conducted within remained secret and sacred.



The facade and stairway of the ziggurat of Ur have been reconstructed by the Iraqi Department of Antiquities



### An unsteady base
Bricks were sun-baked, so the buildings were unstable and had to be routinely destroyed and rebuilt. This caused the level of the cities to gradually rise.

### Etemenanki tower
At the centre of Babylonian life was the Etemenanki ziggurat. It had seven storeys, measured 91m (300ft) tall and may have even been finished in silver and gold.

### Hanging gardens
Possibly built by King Nebuchadnezzar II, if they did indeed exist, the hanging gardens were an astonishing feat of engineering.

### Irrigation
Because of the unpredictable flooding of the river, Babylonians developed a complex series of ports and canals, as well as dams across the city.

### Euphrates river
The river ran through the city and was used by merchants and craftsman to transport and trade their goods across Mesopotamia.

## Circa 1750 BCE
Babylonian mathematicians introduce the concept of place value in numbers. Astronomers also name the planets and constellations.

## 1595 BCE
Babylon is sacked by the Hittite king Mursili I. This marks the beginning of the Babylonian 'dark ages'.

## 1595–1155 BCE
The Kassite dynasty rules over Babylonia. They rename Babylon 'Kar-Duniash' but it continues to serve as the capital of the kingdom.

## 1225 BCE
The Assyrian ruler Tukulti-Ninurta I destroys the armies of Babylon and sacks the city. He goes on to become king.

# Seven ways Mesopotamia changed the world

The phrase 'the foundations of civilisation' is often used while talking about Mesopotamia. But what exactly does this mean? Is civilisation simply people living together, or does it involve more? Agriculture had emerged by 8000 BCE, and art was produced for thousands of years before Mesopotamia rose. However, Mesopotamia took these aspects of human culture and transformed them into civilisation, as we know it today.

Brought together by a common goal – to find food – the Mesopotamians developed some of the earliest writing known to man. This writing was borne out of necessity to record accounts and crop yields. However, it later developed to represent more abstract ideas. As people were gathered together, spiritual practices were also refined, and the population began to share a common belief system. With this established, the priests, who claimed to be able to communicate with the gods, took their place at the top of the social hierarchy, and slowly a class system developed. This emphasis on religion inspired moral codes for the people to follow, which led to formal rules and in turn, punishment for those who disobeyed.

A steady food supply meant the Mesopotamians could pursue other aspects of life, such as technology and science. They made ground-breaking advancements in the areas of mathematics and medicine. However, this social structure also revealed the darker aspects of humanity, such as war, slavery and expansion, and with so many people gathered together, diseases spread rapidly.

As the civilisation developed, it inevitably had an influence on other cultures. It is believed that Babylonian astronomy influenced Greece, India and even China. The early Mesopotamian codes of laws also had a profound effect on lawmaking in the Near East, and the introduction of taxes and a standing army influenced countries worldwide. In fact, historians are still exploring the huge impact that Mesopotamia had on the ancient world, and the world we live in today.

## The creation of writing

Writing began in Mesopotamia towards the end of the 4th millennium BCE as a way to record crucial information about crops and taxes in pictorial form. These early tablets developed into a script, which bears close resemblance to writing today. This system of writing is commonly known as cuneiform and comprised of wedge shaped marks in clay. Gradually the number of characters used in cuneiform decreased from 1,000 to around 400, which ensured more clarity in the script. By 2500 BCE cuneiform was developed enough to portray emotions such as fear and hope.

The word cuneiform itself simply means 'wedge-shaped'

The remains of the Code of Hammurabi were discovered in 1901 in excellent condition

## Health care

Medicine in Mesopotamia involved a combination of religious ritual and physical treatments. Mesopotamia had specific doctors with their own offices, beds and equipment and generally fell into two categories – the ashipu, who practised religious medicine, and the asu, who used herbal remedies; generally these two doctors would work together to treat an ailment. The ingredients used in the various treatments ranged from turtle shell and snakeskin to figs and seeds. Mesopotamian doctors recorded their methods of treatment and diagnosis in medical texts, such as the Treatise of Medical Diagnosis and Prognosis.

## Thou shalt obey

Law codes as we know them today were first created in Mesopotamia. One of the earliest examples of Mesopotamian laws is the Code of Hammurabi. The code features 282 laws dealing with a huge variety of issues, from marriage to theft, in great detail. For example, if a man rents a boat to a sailor and it is wrecked, the sailor has to give the man a new boat. Although it is the most well-known, the Code of Hammurabi was pre-dated by other law codes, such as the code of Lipit-Ishtar and those written by the Sumerian king Ur-Nammu, who described the purpose of his laws as protecting the weak from the mighty.

ASSYRIA

**2600 BCE**
The city of Ashur, capital of Assyria, is founded, along with other Assyrian cities.

**1813–1776 BCE**
Shamshi-Adad I rules Assyria. He expands the empire, secures Assyria's borders and builds up a powerful army.

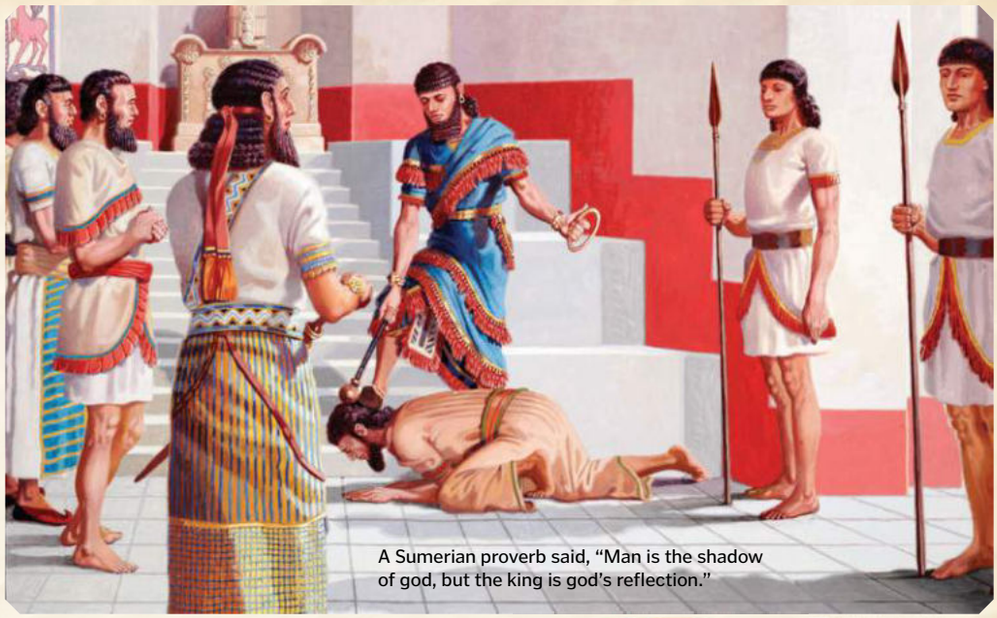
**1472 BCE**
The kingdom of Mitanni, a powerful northern Mesopotamian state, annexes Assyria and the land loses its independence.

**1365–1330 BCE**
Ashur-uballit I defeats the Mitanni, and under his leadership, Assyria develops as a powerful and rapidly expanding empire.

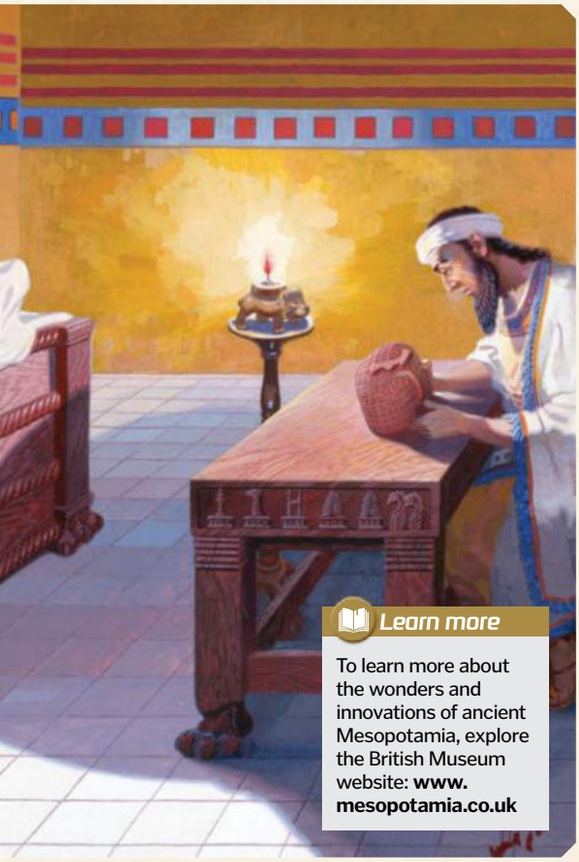
**1244–1208 BCE**
The warrior king, Tukulti-Ninurta I, reigns. Assyria expands to its greatest extent and defeats the ruler of Babylonia.

# Only the strong shall lead

Mesopotamia was made up of several city-states which each had their own leaders and government, with kings ruling over individual regions. This led to a lot of internal fighting between different kings for land and resources. The first kings were the leaders of armies, who then went on to continue to lead during peacetime. Because of the strong emphasis on religion, the kings often served as high priests and therefore were linked to the divinity of god, and claimed to be god's representatives on Earth. Some of these kings, such as Sargon, sought to unite many of the city-states under one leader and capital.



A Sumerian proverb said, "Man is the shadow of god, but the king is god's reflection."



**Learn more**

To learn more about the wonders and innovations of ancient Mesopotamia, explore the British Museum website: **www.mesopotamia.co.uk**

# Mesopotamian money

Mesopotamians used silver rings thousands of years before the first coins were made. In around 2500 BCE a 'shekel' of silver became the currency of Mesopotamia, with one month of labour being worth one shekel, and a slave worth between ten and 20. Prior to this, clay tokens in a variety of sizes and shapes were used for trade and barter. There were at least 16 different types of these tokens that represented various things, such as rope, sheep's milk, perfume and honey.

This Carthaginian shekel from 310-290 BCE is similar to the Mesopotamian shekel

The Standard of Ur, an artefact dating from around 2600 BCE, depicts wheeled chariots being used in battle

# The basis of time

The Mesopotamian's were trailblazers in their concept of time. They were the first in recorded history to use a base 60 numerical system for measuring it with. This led to our 60-second minute and 60-minute hours today. Many believe that it was this base 60 system that helped the Babylonians make such impressive advances in mathematics, as 60 has many divisors. They also used a lunar calendar, which comprised 12 lunar months, at an average of 29.5 days each. This left the Mesopotamians short by around 11 days a year, so they added seven months in each 19-year period to keep the seasons aligned.

The Royal Game of Ur, one of the oldest in the world, was played with early Mesopotamian mathematics

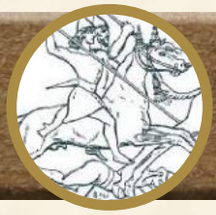
# A wheely late invention

Surprisingly, the wheel was actually invented at a rather late point of human history, with the oldest example from Mesopotamia dating to 3500 BCE, in the Bronze Age. It is likely that the wheel was developed individually by different cultures around the same time. Evidence shows that Mesopotamians used this invention for pottery first, before adapting the design for transport with chariots. Wheels did offer advantages to transportation, but they took a great deal of time to make as smooth as possible, so sledges were still commonly used alongside the wheel.



## 1000 BCE

Assyria establishes the first cavalry force. As this is before the invention of saddles, the warriors ride bareback.



## 668-627 BCE

During his reign, King Ashurbanipal establishes a huge library, housing a collection of thousands of clay tablets.

## 612 BCE

Many Assyrian cities, including Ashur and Nineveh, are sacked and destroyed by a combined force of Medes, Persians and Babylonians.

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# The drones of WWII

## How UAVs first took to the skies over 70 years ago

Now synonymous with distant pilots soaring high above a battlefield they will never see first hand, the roots of today's sleek and sophisticated unmanned aerial vehicles (UAVs) actually stretch back almost a century.

With World War I (1914-1918) providing a crucible for technological innovation, experiments began in unmanned flight. The result was an American 'aerial torpedo' called the Kettering Bug. A forerunner to the modern guided missile, it could carry an explosive warhead at up to 80 kilometres (50 miles) per hour. A timer could be set, shutting off the engine and dropping the wings so that it could plummet like a bomb, but military planners were wary of flying these inaccurate explosives over their own lines.

In the run up to World War II (1939-1945), Britain's Royal Navy experimented with fitting wooden biplanes with radio control so that they could serve as target practice – building up vital skills for the coming conflict, which would see air superiority play a pivotal role.

In 1933, a modified floatplane called Fairey Queen was tested as the first flightless drone aircraft. It crashed on two out of three trials, but in 1934, Queen Bee, a modified Tiger Moth aircraft, followed with greater success.

Training gunners on these rudimentary models wasn't a very realistic simulation, but a solution was soon to come from the United States in the form of British-born actor Reginald Denny, and his Radioplane Company. After years of trying desperately to interest the US Navy in the Radioplane-1, Denny succeeded in 1939 and over the course of the war some 15,374 models of Radioplane were built.

Fast, agile and durable, Radioplanes were fitted with responsive radio control and were better able to mimic the speed and agility of the enemy's fighters.

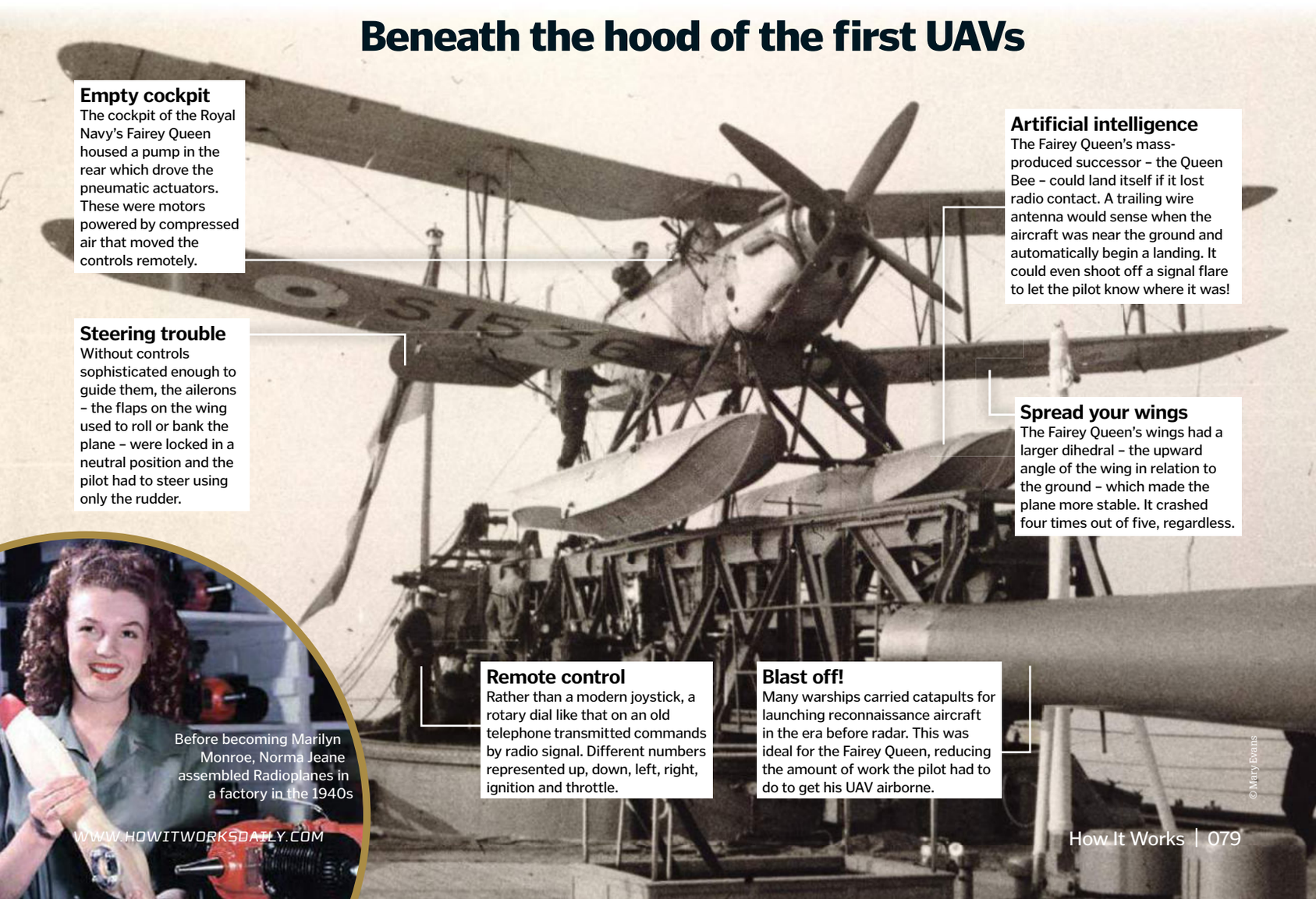
### Drones that fight

While 'aerial torpedoes' represented the destructive capability of drone technology – the end result being Nazi Germany's V-1 and V-2 rockets – the seeds of the concepts for modern UAVs were also sewn behind the red banners of the Third Reich.

Dr Fritz Gosslau proposed Fernfeuer in 1939 – a vision for a remotely-piloted plane, which could drop its payload and then return to base. Plans for Fernfeuer were halted in 1941, but paved the way for development of the V-1 flying bomb.

In March 1944, the US Navy deployed the TDN-1 assault drone in the fight against Japan. On 19 October 1944 it successfully dropped bombs over targets in the Pacific. Unlike the planned Fernfeuer and current UAVs though, TDN-1 had no way of flying home.

## Beneath the hood of the first UAVs



**Empty cockpit**
The cockpit of the Royal Navy's Fairey Queen housed a pump in the rear which drove the pneumatic actuators. These were motors powered by compressed air that moved the controls remotely.

**Steering trouble**
Without controls sophisticated enough to guide them, the ailerons – the flaps on the wing used to roll or bank the plane – were locked in a neutral position and the pilot had to steer using only the rudder.

**Artificial intelligence**
The Fairey Queen's mass-produced successor – the Queen Bee – could land itself if it lost radio contact. A trailing wire antenna would sense when the aircraft was near the ground and automatically begin a landing. It could even shoot off a signal flare to let the pilot know where it was!

**Spread your wings**
The Fairey Queen's wings had a larger dihedral – the upward angle of the wing in relation to the ground – which made the plane more stable. It crashed four times out of five, regardless.

**Remote control**
Rather than a modern joystick, a rotary dial like that on an old telephone transmitted commands by radio signal. Different numbers represented up, down, left, right, ignition and throttle.

**Blast off!**
Many warships carried catapults for launching reconnaissance aircraft in the era before radar. This was ideal for the Fairey Queen, reducing the amount of work the pilot had to do to get his UAV airborne.



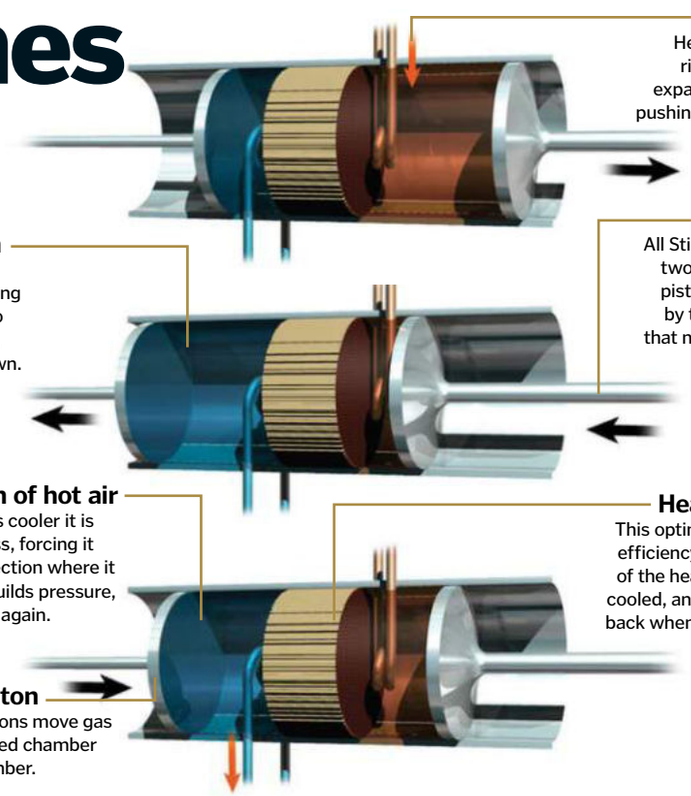
Before becoming Marilyn Monroe, Norma Jeane assembled Radioplanes in a factory in the 1940s

# Stirling engines

## How does this 200-year-old design convert heat into mechanical energy?

A Scottish clergyman named Robert Stirling invented the Stirling engine in 1816. He hoped to create an engine that was safer and more efficient than its steam-powered rivals, which had already existed for roughly a century. The release of the Stirling engine was met with much enthusiasm, but the rise of internal combustion engines saw it sidelined by many companies.

Stirling engines work by repeatedly cooling and heating the same volume of gas, using its expansion and compression to move two pistons and drive an engine. This mechanism is experiencing somewhat of a revival, as it is perfect for use in solar plants where it can produce continuous power as the Sun warms the solar panels. They can also run backwards to create super coolers for use in superconductivity and electronics research.






# Inside the Caspian Sea Monster

## Find out why this monstrous Russian aircraft worried the West for so many years

Dubbed the "Caspian Sea Monster" by US Intelligence, this 92-metre (301-foot) long Russian ekranoplan (a mixture of airplane and hovercraft) was spotted during the height of the Cold War in 1966, by an American spy satellite while it scanned the Caspian Sea. Initially it baffled the West due to its odd shape and intimidating size, which made it poorly suited for traditional sea to air flight.

The Sea Monster's actual function was to fly very close to the water or ground, producing a cushion of air that increased its lift and made it more efficient than a traditional aeroplane. This phenomenon is known as 'ground-effect' and could have allowed the vehicle to fly low enough to be undetectable by enemy radar at the time, ferrying hundreds of troops and armoured vehicles across the water in secret.

The only model of the Caspian Sea Monster was unfortunately crashed in 1980 after a pilot error, and was much too heavy to recover from its watery grave. Plans were made to deploy over 100 similar planes during the 1990s, but the end of the Cold War also put an end to these developments, leaving only a handful of ekranoplans in existence.

This gigantic aircraft was capable of reaching speeds of 500 kilometres (311 miles) per hour

# BRAIN DUMP

Because enquiring minds need to know...

## Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

## MEET THE EXPERTS

Who's answering your questions this month?

**Luis Villazon**

Luis has a degree in zoology from Oxford and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

**Laura Mears**

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

**Alexandra Cheung**

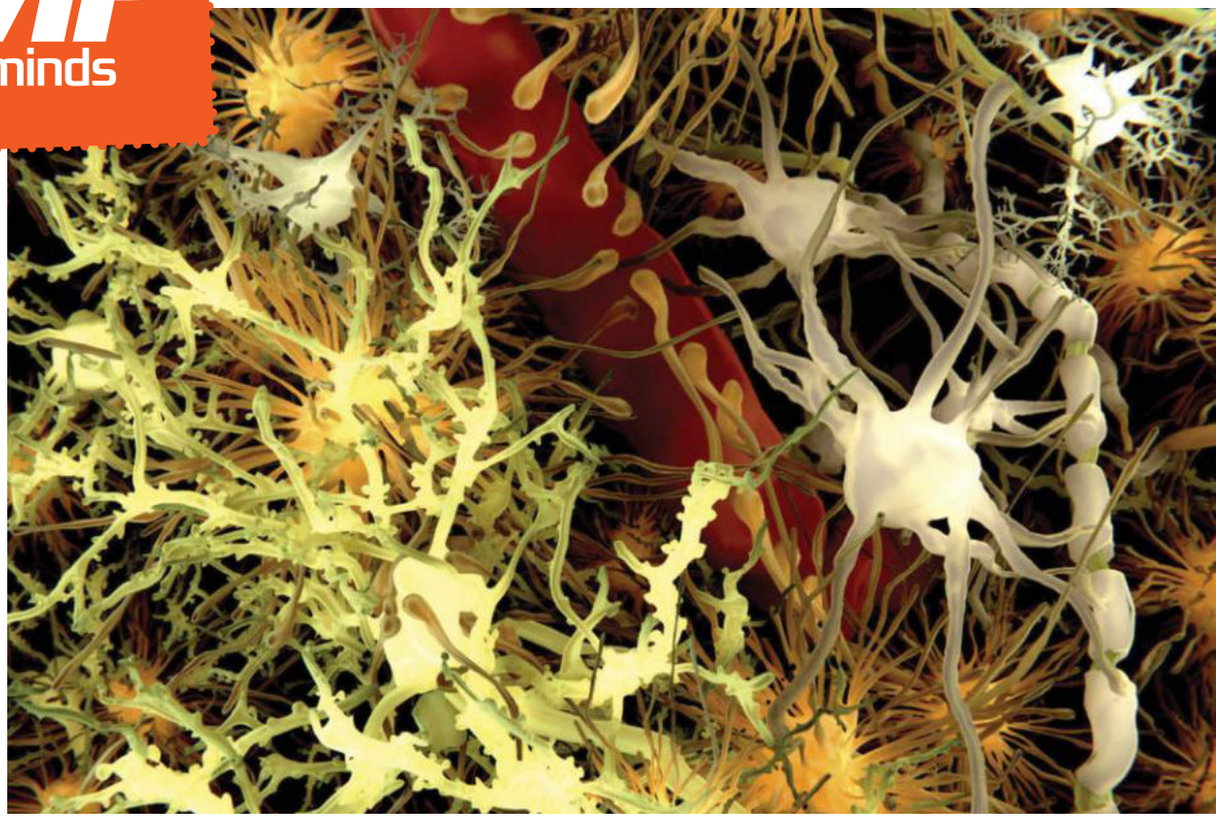
Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

**Ella Carter**

Fascinated by the underwater realm, Ella studied marine biology and oceanography at university before embarking upon a career in publishing. She adores the natural world and loves researching and writing about the wonders within.

**Gemma Lavender**

Gemma is the Features Editor of our sister magazine, **All About Space**. She holds a master's degree in astrophysics and has been elected as a fellow of the Royal Astronomical Society.



Nerve cells in the brain are supported by glial cells

# When does your brain stop growing?

**Denis Brett**

By the time a child is two years old, their brain is around 80 per cent of its adult size, but it continues to grow right up until they reach their mid-20s. However, most of this growth is not driven by the nerve cells themselves. Babies are born with almost all of the nerve cells that their brains will ever need, and the increase in size is mostly down to an increase in the number of support cells, also known as glial cells. These fill the gaps between nerve cells, and play a vital role in cleaning up debris, providing nutrition, and physically supporting and insulating the neurons in the brain. As children develop, new connections are also made between neighbouring nerve cells, contributing to brain growth. **LM**

A worker honeybee protects the hive, even if it means sacrificing itself

# Why do bees die after they sting you?

**Kate Morris**

Bad news for picnic fans, bumblebees and wasps can survive multiple stings – it's only the worker honeybees that die after administering a sting. The reason for this is due to the design of the stinger itself – shaped like a harpoon, the honeybee's stinger lodges itself into the target and is so effective that the bee cannot pull free. When it tries to get away, the bee self-amputates the stinger and with it removes part of its digestive tract, as well as some nerves and muscles. Unfortunately, the bee cannot survive this trauma and dies as a result. **EC**

## Who decides which emojis are made?

**Patrick Caroll**

Mobile phone manufacturers do. The little pictures of things like a dog or a slice of cake were popularised by Japanese mobile networks and don't have any official translation or meaning. Around 1,300 emojis have subsequently been adopted by the Unicode standard, and theoretically anyone can submit a proposal to unicode.org for a new one to be added. But the review process takes about two years and there is no requirement for mobile phones to only use standard Unicode emojis. Apple, for example, has their own set that are used on iPhones and these aren't licensed to anyone else. **LV**

## Why do British schools get six weeks holiday every summer?

**Anna Ramirez**

The long summer break cherished by school children, university students and teachers alike is actually a product of Victorian schooling, when the school calendar was required to fit in with the agricultural one. In the 19th century, when many families farmed the land, hard-working parents needed the extra manpower of their children during the summer months, and the kids were expected to muck in and help with work in the fields. Similarly, they were needed during spring to sow crops and in the autumn to help with the harvest – old traditions that still tie in with British school holidays today. **EC**

British school holidays may change to include shorter, more regular breaks throughout the year

100 per cent fruit juice made from concentrate usually has the same vitamins as the fresh stuff

## What does juice 'from concentrate' mean?

**Lauren Harnett**

Removing the water from fruit juice produces a concentrated liquid, which can be returned to its original form by simply adding water. Concentrate is typically a seventh of the volume and weight of the original juice, making it easier to store and transport. Before extracting its water, the juice is pasteurised to destroy harmful bacteria. It can also be frozen to enable it to be stored for longer. When restoring the water content, oils and essences are often added in to bring back the original flavour. '100 per cent' juices from concentrate typically have the same nutritional value as fresh juice. **AC**

## Why is a ship's speed measured in knots?

**Pablo Levine**

Early sailing ships measured their speed by throwing a floating anchor overboard and measuring out the line it was attached to. This line was knotted every eight fathoms (about 14.4 metres/47 feet) and the sailor counted the number of knots that passed through his fingers in the 28-second interval of a standard ship's hourglass. There are approximately 1,000 fathoms in a nautical mile (1.85 kilometres/1.15 miles), so one knot was extremely close to one nautical mile per hour. Nowadays the knot is defined to be precisely a nautical mile per hour, and it is still useful because maritime charts mark distances in nautical miles. **LV**

Efficient sailing uses the minimum effort to achieve the maximum knots

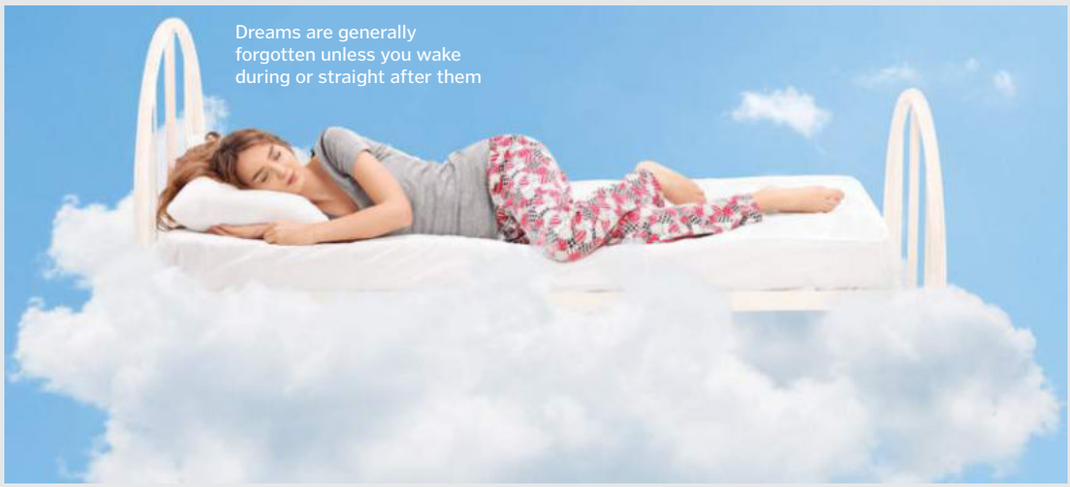
## FASCINATING FACTS

### What's the difference between prebiotic and probiotic?

Probiotics contain live bacteria, while prebiotics contain carbohydrates that bacteria can use as fuel. The former can be found in foods like live yogurt, and the latter in fibre-rich foods, like oats, beans and vegetables. **LM**

Probiotics and prebiotics can be found in everyday foods like live yogurt and oats

# BRAIN DUMP



Dreams are generally forgotten unless you wake during or straight after them

## Why do we have trouble remembering our dreams?

**Tracy Neale**

Research using positron emission tomography (PET) to measure brain activity has found that people who tend to remember their dreams in the morning, have more activity in an area of the brain that processes external stimuli. These people are more likely to respond to sounds while they sleep, and they spend longer periods awake each night, in between dreams. In general, you will only remember a dream if you wake up during or immediately after it finishes. And even if you do wake in the middle of the night, many dreams fade by the morning because they are so jumbled that they don't make an easily remembered sequence. **LV**

Stretching out in a cool area helps cats to regulate their body temperature in hot weather

## How do cats cool themselves?

**Charles Williamson**

Cats have a limited ability to sweat, but several other methods enable them to stay cool when the temperature rises. Cats can sweat from their paws, but these have a relatively small surface area, only allowing for a small amount of cooling. When it's hot, cats seek out shady areas and cool surfaces, such as a tiled floor, stretching out to maximise their surface area and let heat escape. They also groom themselves more frequently, making their coats damp with saliva. As it evaporates, the saliva removes some of the heat, using the same mechanism as sweating. If they get very hot, cats are also able to pant like dogs. The rapid breathing enables saliva and moisture from their lungs to evaporate, getting rid of excess heat. You can help keep your cat comfy in hot weather by providing it with a cool spot to shelter and plenty of water. **AC**

# FASCINATING FACTS

## What do the numbers on credit cards mean?

The first digit of the long number signifies the system (such as 4 for Visa and 5 for MasterCard). The next three, four or five digits represent the issuing bank and the rest are your unique card number. **LV**

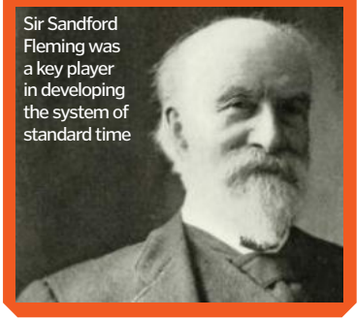

## Where does the term 'break a leg' come from?

According to one theory, the phrase is derived from the Yiddish 'Hatsloche un Broche' (success and blessing), which was mistranslated into German as 'Hals und Beinbruch' (broken neck and leg), before being adopted in English. **AC**

The phrase 'break a leg' is believed to have been popularised by pilots during World War I

## When did we start using time zones?

Global time zones were first adopted in 1884 after an international conference called for a single prime meridian for timekeeping. The Greenwich Meridian was the most popular suggestion, and the international 24-hour system of time zones developed from this. **GL**



Sir Sandford Fleming was a key player in developing the system of standard time

# Why does water taste different after being left out overnight?

**Eva Healy**

According to water chemist Susan Richardson, interviewed by *Wired* magazine, no proper scientific studies have ever been conducted to answer this question. However, there are lots of possible explanations. In the UK, and in the US, chlorine is added to drinking water to keep the public water system clean.

As it comes out of the tap, it still contains traces of the chemical, but left overnight, some of the chlorine will evaporate into the air, changing the taste. Carbon dioxide gas dissolving in water makes it more acidic, and other chemical contaminants from the air could also affect the flavour. **LM**

Chlorine is added to drinking water during the treatment process


It's a myth that fingernails continue to grow after death

# Do your fingernails and hair grow after death?

**Clive Ketteridge**

It is a myth that nails and hair continue to grow beyond the grave – but as skin becomes dehydrated and retracts, it may give the impression that they have grown. Cell division at the base of nails or in hair follicles causes nails and hair to lengthen. This process, however, requires energy, which is produced when cells burn glucose in the presence of oxygen. Once a person stops breathing, oxygen levels in the blood tail off and cell division stops. But as the skin loses moisture, it pulls back to expose more of the hair or nail, making them seem longer. **AC**

# Why do dogs and cats like being stroked?

**Jon Weinstein**

In the wild, dogs and cats show affection and respect to their species by licking, grooming and cleaning – activities that can foster strong bonds between individuals. When we cuddle up to our pets, stroking can mimic this and helps us to connect with our furry friends. It's also thought that in mammals the act of stroking furry skin, and the sensation of being stroked, stimulates a pleasure and reward response in the brain. This could explain why humans love a good head rub in the same way that dogs and cats love a scratch between the ears. **EC**


Cats and dogs show loyalty differently, but they both love a scratch from their owners


Bacteria transfer onto food more rapidly from a smooth surface

# Is there any scientific truth behind the five-second rule?

**Harvey Li**

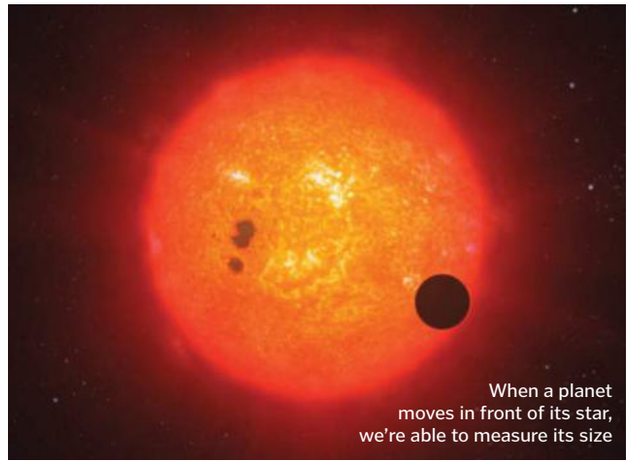
This is something that is still debated, but scientists have done some interesting experiments testing food left on various contaminated surfaces for different amounts of time. However, some of the research has not been peer reviewed (checked by other experts), so it is hard to draw firm conclusions. In general, the findings from these different experiments showed that bacteria start transferring onto food almost as soon as it hits the floor, and their numbers increase over time. If the food hits a smooth bacteria-coated surface, like wood or laminate, it can become unsafe to eat very quickly, but if it hits carpet, the bacteria transfer much more slowly. **LM**

# How is the size of a planet measured?

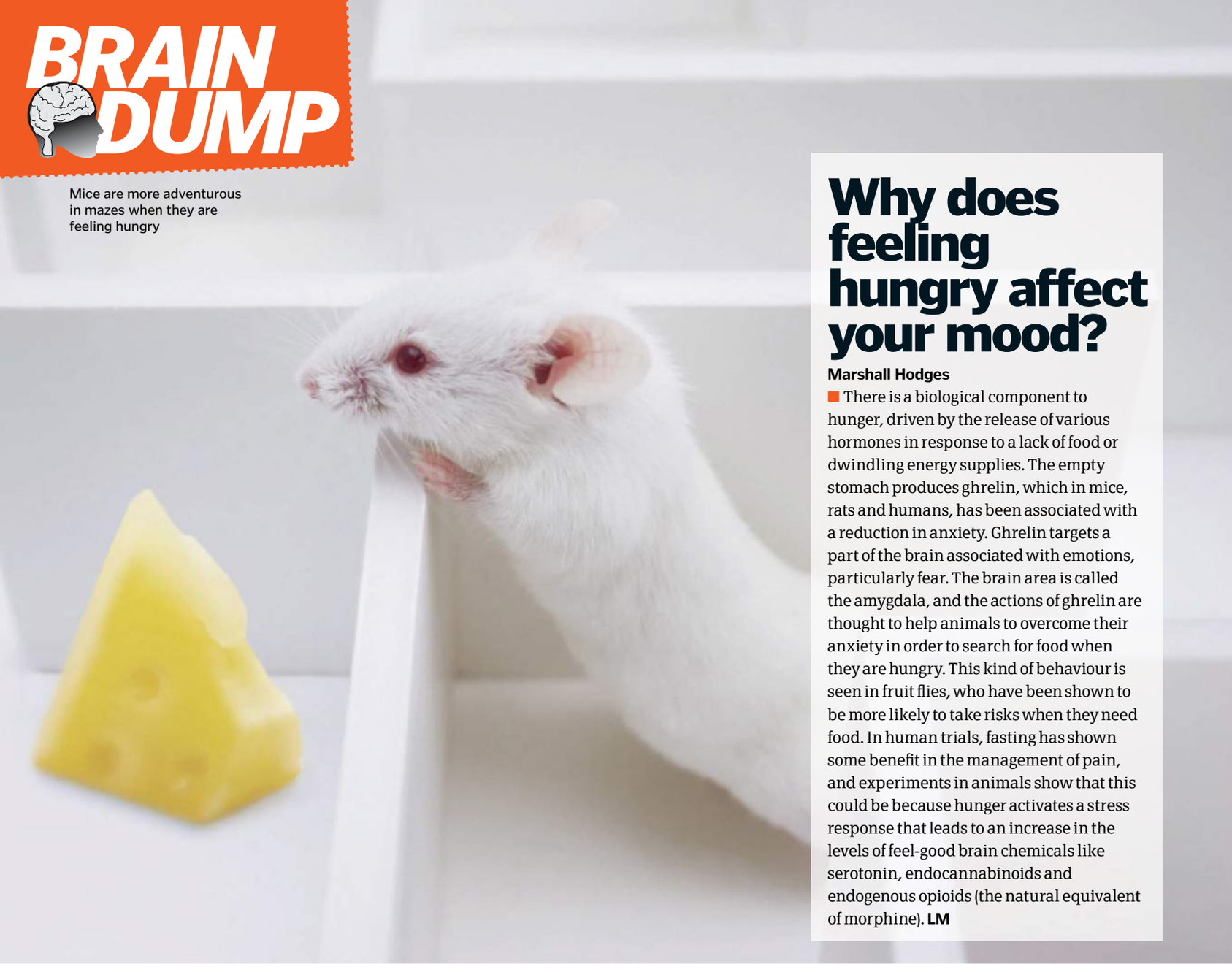
**Katie Foot**

In order to measure the size of a planet, we can use the transit method. This technique involves measuring the amount of light blocked out by a planet as it moves across its star, according to our line of sight. From this, we are able to calculate the distant world's diameter and also its mass.

If we're unable to use the transit method to work out the planet's size, then we're able to use the radial velocity method. When a planet moves in its orbit, its parent star will also move in its own small orbit in response to the alien world's gravity. We're able to measure the mass, which in turn, gives us a rough estimate of its size. **GL**


When a planet moves in front of its star, we're able to measure its size

# BRAIN DUMP



Mice are more adventurous in mazes when they are feeling hungry

## Why does feeling hungry affect your mood?

**Marshall Hodges**

There is a biological component to hunger, driven by the release of various hormones in response to a lack of food or dwindling energy supplies. The empty stomach produces ghrelin, which in mice, rats and humans, has been associated with a reduction in anxiety. Ghrelin targets a part of the brain associated with emotions, particularly fear. The brain area is called the amygdala, and the actions of ghrelin are thought to help animals to overcome their anxiety in order to search for food when they are hungry. This kind of behaviour is seen in fruit flies, who have been shown to be more likely to take risks when they need food. In human trials, fasting has shown some benefit in the management of pain, and experiments in animals show that this could be because hunger activates a stress response that leads to an increase in the levels of feel-good brain chemicals like serotonin, endocannabinoids and endogenous opioids (the natural equivalent of morphine). **LM**

# FASCINATING FACTS

### What is the longest river in the world?

The Nile comes up top as the longest continuous river channel. Measured from its farthest stream in Burundi to the Mediterranean, it is a lengthy 6,695 kilometres (4,160 miles). **EC**

Beginning in the highlands of Eastern Africa, the Nile's journey ends at the delta

## Can a planet exist without a star?

**Stephen Evans**

Yes, these worlds that wander freely around the universe without being in orbit around a star are known as rogue planets. Several free-floating planets have been found in recent years and they are thought to be comprised of mostly gas. Rogue planets are thought to form in one of two ways, either in a planetary system – similar to how the worlds in our Solar System were made before being cast out by their parent system – or alternatively, they may never have been bound to a parent star in the first place. An object that has a mass similar to a planet but isn't able to sustain fusion in its core, may have been made in a similar way to a star – from the collapse of a giant gas cloud. **GL**

Planets that don't orbit a star are known as rogue planets

It is thought that browser cookies are named after fortune cookies, because they both contain messages inside

## What are computer 'cookies'?

**Maureen Love**

Cookies are a way for web sites to remember you. When you click 'View basket', the website needs to know which shopping basket to display from its database. Your Internet Protocol (IP) address isn't enough because all the computers connected to your home router will share the same IP address. Instead, the website saves a unique serial number on your computer in a little text file called a cookie. Every time your browser requests a page from a website, it looks to see if there is a cookie saved for that site and sends it if there is. Cookies can be useful because they enable the website to remember your login details each time, but they are also controversial because they are used by advertisers to track which websites you visit, so they can decide which adverts to show you. In 'private browsing' mode, your browser won't store any cookies. **LV**

Goggles can protect you from the chloramines formed in pool water

## Why does swimming pool water irritate your eyes?

**Thomas Barber**

Chlorine in pool water reacts with sweat, urine, bacteria and oils to form compounds which can irritate eyes. Chlorine is added to the water in order to kill bacteria and other disease-spreading organisms, but does not cause irritation itself. As it reacts with nitrogen and ammonia, it forms chloramines, compounds which can irritate eyes, lungs and skin, and are also responsible for that typical swimming pool smell. The more chloramines that are formed, the less effective the chlorine is at disinfecting the water. By showering before entering the pool, swimmers can avoid introducing substances that lead to chloramines being produced. **AC**

The clouds move as fast as the wind blows them

## How fast do clouds move?

**Jacky Bourke**

Clouds on Earth move as fast as the wind is blowing them. The stronger the wind, the faster a cloud moves. On our planet, clouds can be found at different altitudes and move in different directions and speeds.

Wind speeds in the atmosphere vary with altitude, so the major factor in a cloud's movement is its height above the ground. In general, the higher up in the atmosphere you go, the faster the winds and therefore, the faster the clouds are being pushed along. High-altitude clouds in the jetstream, for example, can reach speeds of over 322 kilometres (200 miles) per hour. **GL**

## Why do koalas sleep so much?

**Richard Judd**

Koalas need 18-22 hours of sleep per day. This isn't because the little critters are lazy; their diet of eucalyptus leaves requires them to conserve as much energy as possible. It's a common misconception that the oil in eucalyptus leaves 'drugs' them, and the ultra-sleepy state is a result of being drunk. However, the koalas need to sleep so much in order to digest and break down their food, which is incredibly tough, full of fibrous material, low in nutrition and contains toxins which take a long time to digest. Koalas eat between 200 to 500 grams (7.1 to 17.6 ounces) of eucalyptus per day – a leaf that is generally poisonous to other animals. However, a specially developed digestive system enables the koalas to extract the nutrients needed from the leaves and detoxify the chemicals. They also extract water from the leaves, which is why koalas don't need to drink much water. **EC**

When not snoozing, koalas spend their time eating, grooming or looking for mates

A helium balloon floats because the helium inside is lighter than the equivalent volume of air

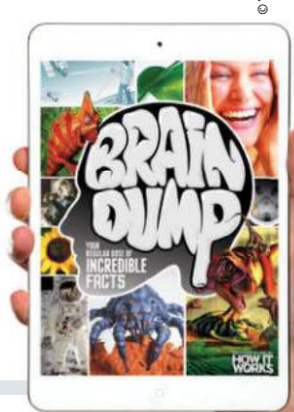
## How high will a helium balloon be able to go before popping?

**Toby White**

This depends on how heavy the balloon is and how quickly it's losing helium through the material that makes the balloon. A helium balloon will continue to float higher until it reaches an altitude at which the surrounding air has the same density as the helium inside. Air pressure reduces the higher up in the Earth's atmosphere you go, so as the balloon travels beyond this point of equal pressure, it will expand to try and keep the pressure inside and outside of it the same. The balloon material can only stretch so far before the expansion causes it to explode. **GL**

## New Brain Dump is here!

Don't miss issue 29 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 October. You'll find out how medical professionals manage to bring people out of comas, who would win in a fight between the T-Rex and the Spinosaurus, and the answer to the question: why are ships called "she"? Every edition is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is @BrainDumpMag.



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# THE WISH LIST

The tech behind the latest must-have gadgets

# Health gadgets

From hi-tech sleep monitors to UV sensors, check out the latest tech to keep you fit and healthy

**Sensor protection**
When not in use, the section that holds the sensor draws back into the main body to protect it from getting damaged.

**Easy operation**
Once it is next to the desired object, pushing the central button activates the molecular sensor.

**Real-time analysis**
The SCiO connects to a cloud-based service that reviews the data you've collected and quickly sends back the results.

## 1 Analyse food's chemical make-up

**SCiO**

$249 (approx £165)

**www.consumerphysics.com**

The SCiO is the world's first molecular sensor that fits in the palm of your hand, featuring a tiny spectrometer that scans the molecular fingerprint of an object and provides relevant, instant information about its chemical make-up. It can tell you the number of calories and the amount of sugar within food, but can also analyse medicines to see what's inside. It weighs a mere 35 grams (1.2 ounces) and records a measurement in 1.5 seconds. Its tiny optical sensor is the key to this technology, which works by absorbing reflected light from an object. The obtained spectrum is sent to SCiO's cloud software for analysis, and the result is then sent directly to your smartphone. The ability to get instant information about the chemical composition of almost anything is incredibly exciting not just for health; the SCiO has an endless list of potential applications.


## 2 Protect your skin from UV

**LilyPad UV sensor**
$99 (approx £65)
**www.usvigilant.com/lilypad**
Knowing when to reapply your sun cream is always a difficult task, especially if you're dealing with children. The LilyPad takes away all your worries, as its Wi-Fi-enabled UV sensor constantly monitors the sunlight and tells you when its time to reapply. It does this by measuring the Sun's intensity, alerting you when it rises to a potentially harmful level. The pad itself weighs only 140 grams (4.9 ounces) and is designed to float in the pool with you, connecting to your smartphone via Bluetooth. It's compatible with iOS and Android, and will keep your mind at peace when enjoying the sunshine.


## 3 Smarten up your yoga mat

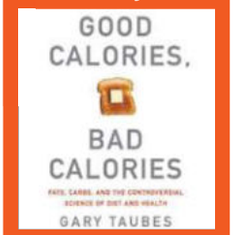
$297 (approx £195)
**www.smartmat.com**
The new SmartMat has the technology to take your downward facing dog to the next level. It looks like a normal yoga mat, but provides both spoken and visual cues via the accompanying app to help correct your position. It is comprised of four separate layers that measure pressure, enabling it to analyse your technique as you perform each pose. What's brilliant about the SmartMat is that is rolls up like a regular mat and is the same size, meaning it can be taken with you to classes if you prefer to do your yoga with others. If it's set up correctly, it can differentiate between a whopping 62 different positions!

## 4 The ultimate fitness watch

**Fitbit Surge**
£199.99 / $249.95
**www.fitbit.com**
Dubbed the "fitness super watch" by Fitbit, the Surge is by far its most advanced piece of fitness technology. It constantly monitors your heart rate, and tracks your activity all day long. It is fully adaptable to any sport, recording your workout and exercise summaries whether it's tennis, football, curling or croquet. The watch can also see call and text notifications from your mobile, and monitors your sleep automatically. The battery lasts for an impressive seven days meaning you'll only need to charge the Surge once a week, an impressive feat compared to many of its contemporaries.


## EXTRAS

The resources to help you stay fit and healthy




**BOOK**

### Good Calories, Bad Calories

**£15.99 / $17**
**www.amazon.co.uk**
*The Diet Delusion*, as it's known in the UK, looks at why we struggle to stay healthy in an age where huge advances in healthcare have been made. It exposes the truth behind our diet and health, as well as the ways in which pharmaceutical companies mislead us.

**APP**

### Sickweather

**Free**
**iTunes**
To stay healthy you need to avoid getting sick. Sickweather gives real-time maps of illnesses around your location by examining social media reports, and then adds markers onto a map of the area. It doesn't sync with Apple Health, but it is still a very clever app.


**WEBSITE**

### health.com

With a whole host of sections ranging from diet and fitness to beauty, this website aims to provide all your health needs and is a great place to pick up new recipes and innovative fitness tips. It's a must for any health fanatic.


## 5 Intelligent digital thermometer

**TempTraq**
$24.99 (approx £16)
**www.temptraq.com**
A child's temperature can be used to assess their overall health. TempTraq is the first 24-hour intelligent thermometer on the market that continuously monitors and records this vital piece of information for constant review. All of the data it compiles is sent directly to your smartphone; it can even send alerts if it detects an unusual temperature. The patch is designed to operate wirelessly, and is made of a soft, latex-free material to ensure it's comfortable for the child to wear. The accompanying app can monitor more than one child if necessary, and has specialised functions such as 'fever alert' when a temperature spike is recorded.


## 6 Hi-tech sleep monitor

**Sense**
$129 (approx £84)
**www.hello.is**
Scientists have long known that your internal clock helps your body decide when to fall asleep and wake up. Anything that disrupts this natural body rhythm can leave you feeling groggy, affecting your ability to think clearly and perform tasks well. 'Sense' sits on your bedside table and listens out for loud noises while also monitoring air and light quality. The gadget includes a small sensor that clips onto your pillow, monitoring movement throughout the night. Once you wake in the morning all of this information is available to you via an app, so you can see how well you slept and what caused you to wake up or move around during the night. The brilliant thing about Sense is the more you use it the more it can help you, making more informed decisions about your perfect sleep environment.

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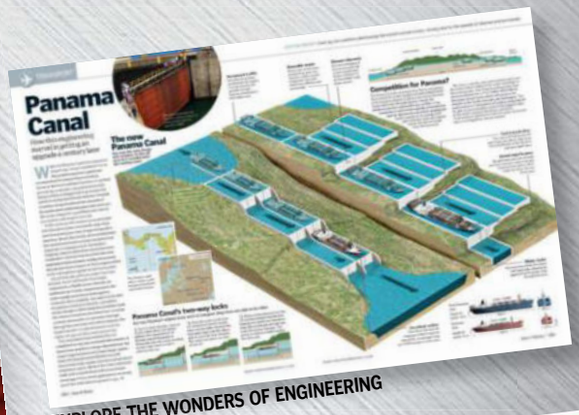


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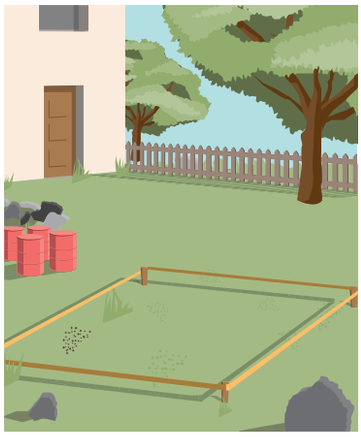
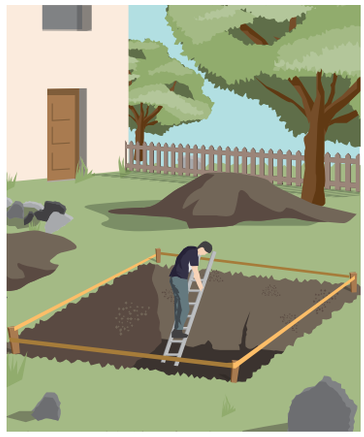
# Build a nuclear shelter

Build a safe haven to protect you from both the blast and the radioactive fallout



### 1 Choose your location

Your nuclear shelter should be located in an area you can quickly access, far away from any flammable materials. Nuclear weapons emit vast amounts of thermal radiation during the blast, which can cause damage well beyond the main blast radius. If you can't dig somewhere that meets these criteria, ensure you have a fire extinguisher to combat any fires and try to clear the area of flammable materials.



### 2 Dig your trench

Once you have gathered the appropriate tools, you're ready to start digging. The trench can be as deep as you want, but ideally you should be able to stand and move around comfortably, as you may be stuck inside for a while should the worst happen. The deeper you dig, the better blast protection you will have; it may be worth spending a few extra hours on it. Remember to dig two separate routes to get in and out of the shelter.

### 3 Construct your roof

Wooden logs or metal poles should form the foundation of your roof; make sure they are cut at least 30 centimetres (12 inches) longer than they need to be, so that they comfortably span the hole you've dug. Cover the structure with a sturdy tarpaulin, and then cover that with soil from the hole. We recommend that this soil layer is at least 50 centimetres (20 inches) thick to provide the best radiation protection.

### 4 Fortify your shelter

Once the basic structure is complete and the roof is secure, it's worth spending time adding some extra features to your shelter. Adding a separate toilet area would be advantageous, as well as incorporating a bed made from wooden slats. It's a good idea to put wooden frames around the exits in order to strengthen them, and this will also stop them from collapsing under the weight of the soil above.

**DON'T DO IT ALONE**
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

### 5 Stock up on supplies

If there were to be a nuclear blast, you're going to need to remain inside your shelter for at least two weeks, maybe even longer. Keeping it well stocked with provisions is therefore essential; drinking water and food are a must, as are power sources and a means of communicating with the outside world. If you really want to splash out, an air filtration system would be a superb addition to any shelter, but is rather costly and requires a large power source.

### In summary...

Although the chances of you actually needing to use your shelter are slim, it's good to have a plan in case such a disaster were to happen. If you can't create a shelter like this, you can use a room in your house – preferably a basement that has no outside walls, to provide the best possible protection from radiation.



**NEXT ISSUE**
- Build your own robot
- How to make invisible ink

# Make a model heart chamber

See how the amazing muscles in your heart keep blood pumping around your body

Illustrations by Edward Crooks

**1 Fill your jar**
Take a medium sized beaker or a wide-mouthed glass jar, and half fill it with water. You will then need a large balloon, which will work to seal off the inside of the beaker. Cut the balloon at the neck, just before the part that widens into the main balloon. Don't throw away the small neck part that you've cut off, as you will need it later in the experiment to help construct one of the valves.

**2 Attach your balloon**
Take your balloon and stretch it over the opening of your glass jar or beaker, making sure you pull it down as tightly as you can so that it holds itself securely in place. The flatter you can get the surface of the balloon, the better. Take a sharp skewer and carefully poke two holes into the flat surface you've created, roughly 2.5 centimetres (one inch) apart from each other, at opposite sides of the jar.

**3 Complete your pump**
Stick a straw through each hole, making sure it fits securely. Air should only be able to enter or leave through the straws. Tape the small part of your cut balloon around one of the straws. Place the jar in a large pan in case of spillages, then bend the straws downwards and gently press in the centre of the stretched balloon. Water will be forced out through the straws, simulating your heart pumping blood.

**In summary...**
This simple experiment simulates one of the heart's four separate chambers. The balloon on the end of one of the straws acts as a valve, stopping blood from re-entering the chamber it has been pumped from. Without these valves, the heart would not be able to transport blood from chamber to chamber and then around the body successfully.

# INBOX
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# WIN!

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## Letter of the Month

# What do blind people see?

Dear **HIW,**
I love reading your magazine every month! It is definitely the best magazine on the market, and is great for aspiring engineers. I have a question that I would like answering. If you are completely blind and you don't see blackness, what do you see? Is it possible to see nothing?
Many thanks,
**Theo J. Codd (aged 14)**

**That's a brilliant question, Theo. Blindness is actually a fairly elastic term used to describe a number of different visual limitations. To be considered legally blind, you have to fall short of a specific standard of visual acuity, which is your ability to distinguish details and shapes of objects. Although most sight disorders and blindness still permit small amounts of sight or light perception, total blindness is possible. This condition, which is called no light perception (NLP), means that the sufferer sees nothing at all. However, some people who have not always been blind but now suffer from NLP describe what they "see" as an ever-changing bright light in a variety of colours, rather than darkness. Research has also revealed that even people with total blindness may be able to perceive light non-visually thanks to special cells in the retina known as intrinsically photosensitive retinal ganglion cells.**

There are around 360,000 people registered blind in the UK, although the real figure is estimated to be around 2 million

## Why does the Earth spin?

Dear **HIW**,
Thank you for another fantastic issue with a huge variety of facts! I have been thinking about the recent supermoon eclipse, and it made me think of a question. What makes the Earth spin around on its axis? I would assume gravity has a part in this, but I would love to know the answer!
Thanks,
**Ben Fuller**

**The reason why the Earth spins is related to the way it was formed. The collapse of a huge cloud of gas and dust triggered the formation of our Solar System, roughly 4.6 billion years ago, caused by its own gravitational pull. As it collapsed it started to spin, throwing material together into swirling masses that eventually formed the planets. As more material joined each planet, they spun faster. Earth keeps spinning because - besides the minor effects of tidal friction generated by gravitational interactions with the Moon - no significant forces act on our planet to slow it down.**

Measured from the equator, Earth is currently rotating at 1,674 kilometres (1,040 miles) per hour

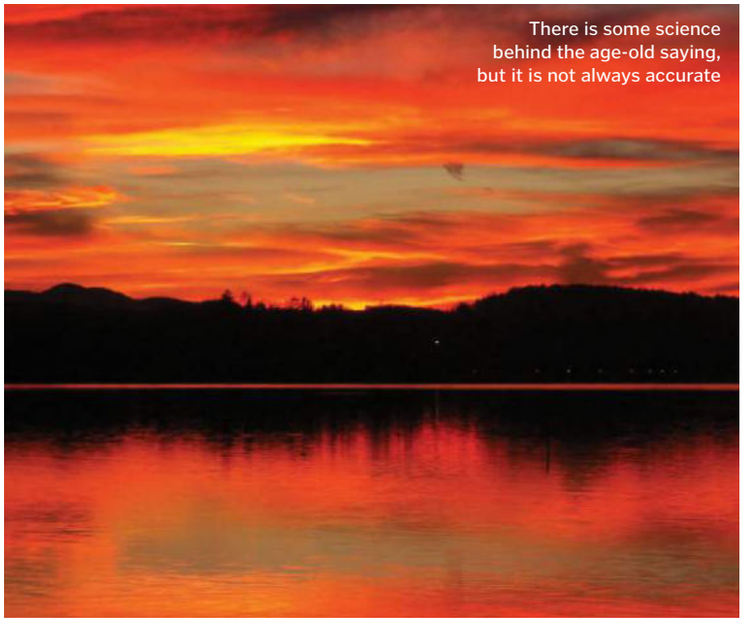
© NASA; Thinkstock

## Mosquito bites

Dear **HIW**,
Thank you for the most amazing magazine ever! Each time I've been to Italy I always get bitten by mosquitos; why do these bites always itch and swell so much?
Thanks,
**Lev Dormidontov (aged 9)**

**This is all down to the body's natural immune response and the production of chemicals called histamines. Your body reacts to the mosquito's saliva, which it injects to stop your blood from clotting, making it easier for them to take a drink. Molecules in your immune system called antibodies bind to this saliva, triggering the release of histamine. This in turn leads to an inflammatory response that makes the bite swell. It also causes the blood vessels near the bite to swell, which irritates nearby nerves causing the small bump to itch.**

Your body's immune system is responsible for the swelling and itching you experience when you get bitten by an insect



There is some science behind the age-old saying, but it is not always accurate

## Red sky at night, shepherd's delight?

Dear **HIW**,
I love the magazine and read it every month. I was wondering why they say "Red sky at night, shepherd's delight, red sky in the morning, shepherd's warning". Is this a myth or is it actually true?
Thanks,
**Emilio Rimini (aged 13)**

**This saying refers to the red appearance of the sky when dust and small particles become trapped in the atmosphere, scattering blue light while allowing red light through. There is actual science behind the theory that a red sky at night suggests good weather is on its way: it shows that high pressure is moving in from the west, typically bringing dry and pleasant conditions. Conversely, a red sky in the morning suggests that the high-pressure system has already moved east, meaning that a low-pressure system is likely to hit, bringing wet, windy weather. This prediction method is only really applicable at the mid-latitudes and is not 100 per cent accurate; a number of factors can change incoming weather systems.**

*"This method of predicting the weather is not 100 per cent accurate"*

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**@HowItWorksmag** First magazine I've read from cover to cover in ages. I actually learned something, rather than reading opinions or glorified adverts!

@biggingerdrew
**@HowItWorksmag** thanks for the brilliant magazine you write and all the excellent competitions you run!

@phstd
The recycling journey of a plastic bottle. Great visual. bit.ly/1Falykg **@HowItWorksmag**

@iamviskafian
#FireRainbow – rare phenomenon involving cirrus clouds, ice crystals, the Sun & angles #Science is awesome!

@NASA
Hot, dry summer weather brings large wildfires, charring nearly 7 million acres each year!

@WorldClassFacts
There are more possible ways to play a game of chess than there are atoms in the known universe.

@RichardDawkins
"It may not be your truth but it's true for me. It's my truth." No, if it's true it's true – for everyone. Truth doesn't care about you.




# HOW IT WORKS

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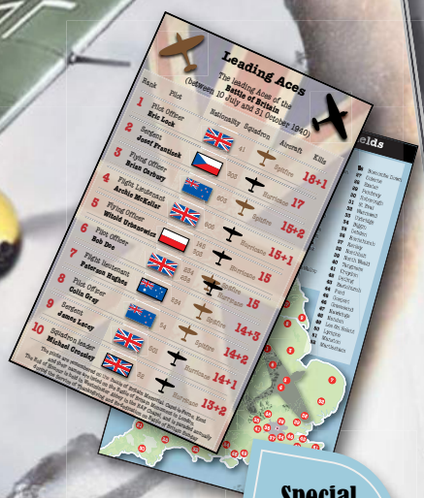


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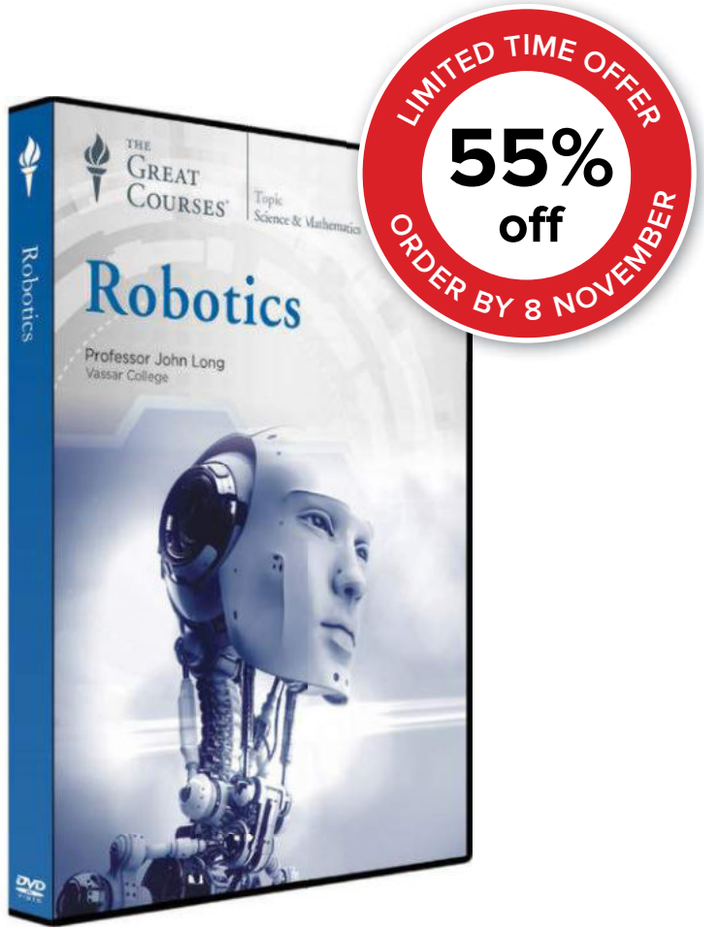


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# The Desert Rats' Cromwell

A vehicle made famous by the British 7th Armoured Division, who had been dubbed the Desert Rats for their exploits in North Africa. However, the 7th Armoured were not issued with Cromwells until 1944, when they returned to the U.K. to prepare for D-Day. They fought in their Cromwells across France and into Germany, and eventually took part in the Victory Parade on September 7, 1945, in Berlin.

Development for the Cromwell first began in 1940 when the General Staff knew the Crusader would soon become obsolete. The tank was the fastest British tank to serve in the war, with a top speed of 40 mph (64 km/h). Its dual purpose 75 mm main gun had HE and armour-piercing capabilities and its armour ranged from 8 mm up to 76 mm overall.

In World of Tanks, you can command the Cromwell from the driver's seat. World of Tanks is an online PC game dedicated to tank warfare in the mid-20th century, with over 300 of history's most iconic tanks.
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